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BATTLE WOUNDS OF THE THORACIC CAVITY

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DURING THE RECENT CAMPAIGN in North Burma there was an unusual opportunity to observe and treat wounds of the thoracic cavity. There were 308 patients with such wounds admitted to the 20th General Hospital during the period from December, 1943, to March, 1945. Six of the wounds were due to bayonets, 153 to bullets and 149 to shell, mortar, grenade, bomb or mine fragments. The high percentage of bullet wounds was due to the fact that this campaign was carried on under conditions which made it largely small arms warfare. There were 240 Chinese, 59 Americans, three Japanese, two Gurkas, two Kachins, one Indian and one Englishman. More than 50 per cent of the patients were received within 36 hours of the time of wounding, while 10 per cent were received within 12 hours. The patients were sent to this hospital as rapidly as their conditions and the circumstances of the campaign permitted. A few patients were received from other fixed hospitals more than three weeks after injury. These obviously represented the residue of a much larger group of patients treated in those hospitals and are not included in this series. It is believed, therefore, that this series of patients is an unselected group of battle wounds of the thoracic cavity. In addition to receiving the patients relatively early, with only a few exceptions we were able to care for and observe them until their wounds had completely healed. In this respect the opportunity was unusual.

Ninety per cent of the patients had been operated upon in the portable surgical hospitals. These hospitals were set up in the jungle as close as possible to the Japanese line, with the minimum of equipment since their supplies were carried on horseback or dropped by parachute. The casualties received sulfonamides locally and by mouth from the first-aid men and reached the portable surgical hospitals from one to eight hours after being wounded. The administration of sulfadiazine by mouth was continued during the entire evacuation. The good results obtained in this series of patients are to no small degree a tribute to the men who worked in those forward echelons.

By and large the surgery undertaken was conservative. The wounds were simply débrided and closed, with little effort to explore the pleural cavity. If sucking could be controlled by suturing the muscles only, the skin was left open. In a few instances there were large open wounds so that the lung was exposed. In these cases the wound in the lung was sutured, the opening in the chest wall closed by a muscle flap if necessary and the lung reëxpanded by thoracentesis. In some instances the skin was also sutured to insure an

air-tight closure. The patients were evacuated to this hospital by air, usually on the following day, but occasionally on the same day.

When the patients arrived in this hospital they were seen immediately, and an effort made to evaluate the severity of their condition. A note usually accompanied the patient describing the operative procedure which had been done in the forward area. We soon got to know the surgeons in the portable surgical hospitals by their work, if not personally. Under such circumstances if the patient had what was expected to be a clean wound and if he showed no evidence of infection, the original dressing was not removed for four or five days. When no note accompanied the patient, or if he had been operated upon by a surgeon with whose work we were not familiar, it was our practice to inspect the wound immediately. During the latter part of the campaign all wounds have been subjected to early secondary suture which greatly reduced the time required for convalescence.

Many of the patients required emergency treatment upon admission to this hospital in spite of excellent early care. This was due to (1) blood loss and shock; (2) a disturbance of the mechanism of respiration; or (3) a combination of these two.

EMERGENCY TREATMENT

1. *Blood Loss and Shock:* When the patient presented a shock-like picture but was found to be aerating his lungs adequately he was treated by the transfusion of whole blood.

2. *Mechanical Disturbance of Respiration:* When the patient was dyspneic it was due to either, or both, of two causes.

   a. *Pneumohemothorax:* Reduction of breathing space by pneumohemothorax, with deviation of the mediastinum to the opposite side was treated by immediate thoracentesis for relief of the dyspnea.

   b. *Tracheobronchial Obstruction:* When there was an intrapulmonary injury with bleeding or excessive pulmonary secretions obstructing the tracheobronchial tree, with patchy or massive atelectasis, constant care was required to encourage the patient to cough and clear the tracheobronchial tree of secretion. Aspiration with a tracheal catheter was occasionally necessary.

   c. *Hemorrhage, Shock, Hemopneumothorax and Tracheobronchial Obstruction:* The sickest patients were those in shock from trauma and blood loss who had severe pulmonary injury with partial obstruction of the tracheobronchial tree by blood and mucus, and whose lung volume was further reduced by an hemopneumothorax. Such patients were given whole blood, subjected to thoracentesis, and encouraged to cough to clear the tracheobronchial tree. Tracheal aspiration was used when necessary.

Only a few patients, however, were still coughing up fresh blood upon admission, but a large number were coughing up old blood and continued to do so for several days. In the patients who needed blood or fluids because of shock or dehydration or both, there was always some hesitation in building

up their blood volume too suddenly for fear of precipitating fresh pulmonary bleeding. This, however, occurred in only one instance, and that was in a patient who inadvertently received 2,000 cc. of fluid in about 45 minutes only 24 hours after being wounded.

In the patients who were dyspneic due to hemopneumothorax, we were fearful that thoracentesis, with early reëxpansion of the lung might precipitate fresh pulmonary hemorrhage. In no instance, however, did this occur. It should be stated that seldom was over 750 to 1,000 cc. of air or blood removed at a single thoracentesis.

HEMOPNEUMOTHORAX

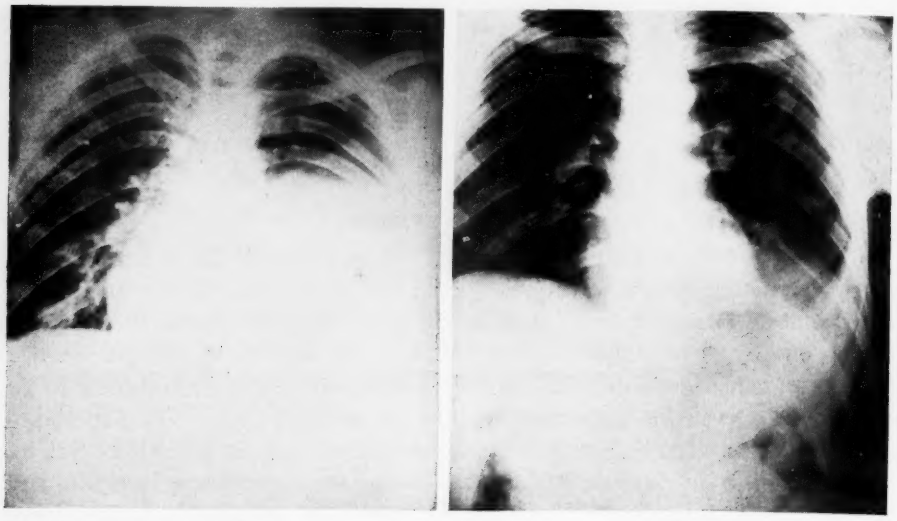
It is agreed by all that if a patient is dyspneic due to the pressure of an hemopneumothorax, thoracentesis should be done immediately to relieve the dyspnea. However, there is some difference of opinion as to the management when dyspnea is not a factor. It was my opinion in civilian practice that there was seldom justification for allowing a massive hemothorax to go untreated, or even for the replacement of the blood by air. The experience with the present group of battle wounds has tended to strengthen that opinion.

Although a few patients have been allowed to absorb large hemothoraces spontaneously, as a rule the blood and air have been removed by one or more thoracenteses as early as seemed reasonable. When dyspnea was not present the first thoracentesis was usually done three to five days after the patient was wounded. About 750 to 1,000 cc. of blood and air were removed at the first aspiration, and this was repeated every day or two until the lung was reëxpanded as completely as possible (Fig. 1). There were 140 patients with sufficiently large hemothoraces or hemopneumothoraces to be diagnosed. Of this group, 103 were subjected to one or more thoracenteses. When the hemathorax was very small it was left alone.

A small number of large hemothoraces were allowed to go untreated. Although the blood was absorbed in all but three cases, two definite impressions were gained. First, the patients had to stay in the hospital longer because of the time required to absorb the hemothorax; and, second, the patients were left with more deformity in the form of a thickened pleura and as a result a partially fixed hemothorax. An additional disadvantage of allowing a massive hemothorax to go untreated or to replacing the blood by air, was the size of the empyema when infection did occur. When infection occurred after the lung had been rapidly reëxpanded by repeated thoracenteses, the empyema was much smaller and responded more rapidly to treatment.

There are only two possible disadvantages to early reëxpansion of the lung by thoracentesis. First, there is the possibility of starting fresh pulmonary bleeding as the lung reëxpands. This did not occur in a single instance in this series in sufficient degree to be diagnosed. The only patient who bled had not had a thoracentesis. It cannot be said dogmatically that no intrapleural bleeding was precipitated, but if so, it was not demonstrable. Second, there is the possibility of introducing infection into the hemothorax. There is no reason to believe that such occurred in any of these patients.

There were 30 patients who developed empyema, an incidence of 9.7 per cent. Of these 30, only seven had negative cultures at their original thoracentesis, and in these the source of the subsequent infection appeared obvious.



1A 1B

FIG. 1.—(A) An hemopneumothorax from a perforating 25-caliber rifle bullet wound, five days after injury.

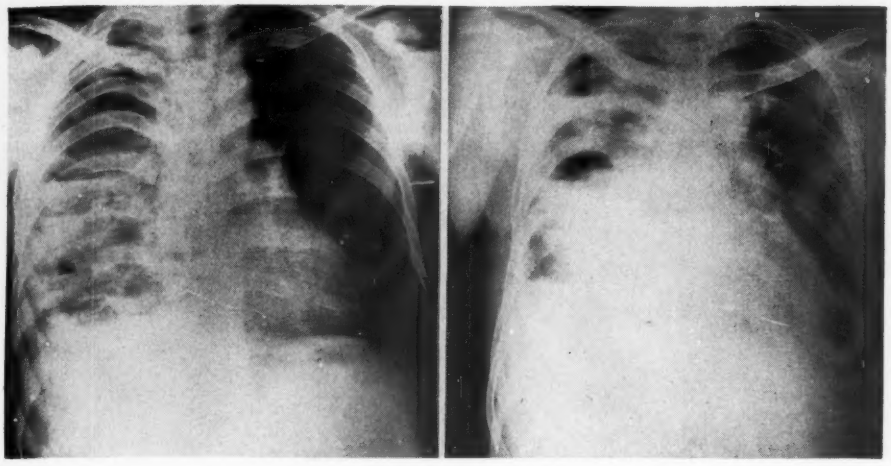
(B) Three days later, after two thoracenteses, the lung was completely reëxpanded and breath sounds came through normally except at the extreme base. The fluid did not reaccumulate. Such a procedure makes early return to duty possible with no disability.

Every patient who developed an empyema had high fever at the time he was admitted to the hospital and continued to have it until the empyema was drained. A number of the patients with hemothorax had considerable fever for some time without developing empyema, but this was the exception rather than the rule. In only ten instances did patients with hemothoraces maintain a fever of 101° F., or over, for more than two weeks without going on to suppuration, and only one patient had such a fever for over three weeks, to have it subside uneventfully. It is probable that the febrile course was due to infection in the lung rather than to uninfected blood in the pleural cavity for many of the patients with hemothoraces had little or no fever. In no instance did a patient with little or no fever on admission develop an empyema after thoracentesis. All these factors together lead one to discount the probability of introducing infection into the pleura by thoracentesis.

CLOTTED HEMOTHORAX

Unfortunately, it was not always possible to reëxpand the lung by thoracentesis when an hemothorax was present. In 11 instances, or 8 per cent of the 140 patients with hemothorax, the blood appeared to have clotted and could not be aspirated satisfactorily. A small amount of clotting very probably occurred in many of the hemothoraces, but only in these 11 was it sufficiently extensive to become a real problem.

Perhaps three of these should not properly be said to have had a clotted hemothorax, but they presented the same problem. They started primarily as pneumothoraces with very little blood. In each instance there was a temporary bronchopleural fistula with infection of the pleural cavity. Serum poured out into the pleural cavity and clotted to form multiple cystic collections which did not communicate freely. They presented multiple fluid levels upon roentgenologic examination (Fig. 2). At operation, these looked just



2A 2B

FIG. 2.—(A and B) shows two different patients with clotted hemothoraces. Both started primarily with a pneumothorax. Serum poured out into the infected pleural cavity to clot and produce the multiple fluid levels demonstrated. Both had open drainage with complete removal of the blood clot. A suction of about 150 cm. of water was applied. Both attained complete reëxpansion of the lungs, with obliteration of the empyema cavity. Both returned to duty.

like the infected serum pocket seen following a total pneumonectomy without drainage.

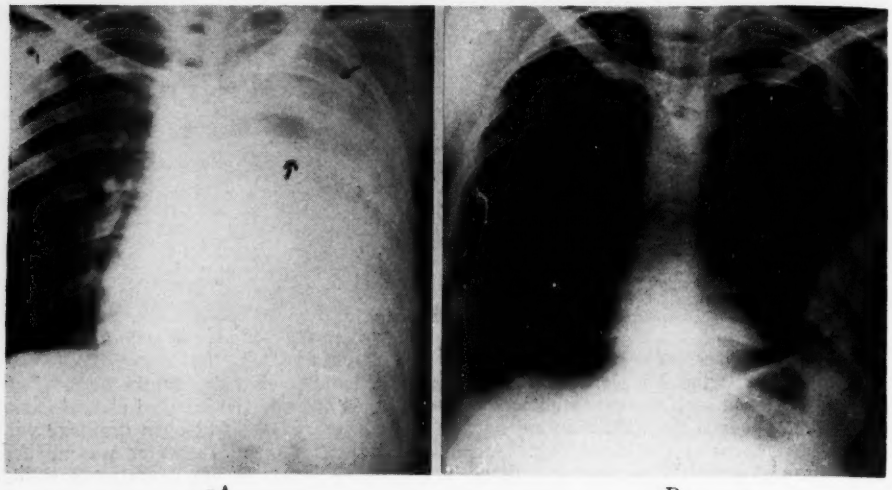
The remaining eight patients had clotting in massive hemothoraces. Here, again, there were multiple cystic collections some of which apparently communicated, while others did not. One could get a small amount of fluid by aspiration almost anywhere in the chest, but when one cystic collection had been emptied the needle had to be moved before additional fluid could be obtained. When air was present, multiple fluid levels were found upon roentgenologic examination (Fig. 3), when no air was present simply a massive density to roentgen ray was found.

Eight of the 11 patients had infection. They will be discussed under the section on empyema. Two of the remaining three patients were treated conservatively early in the campaign; one absorbed his blood to a large degree, but was left with a very much thickened pleura and a partially fixed hemithorax. The other had not absorbed his hemothorax when sent to the Zone of Interior. The third patient was received late in the campaign and was subjected to open thoracostomy, with evacuation of the blood clot and decorti-

cation of the lung as practiced in the Mediterranean Theater.[1] Certainly this appears to be the treatment of choice.

TENSION PNEUMOTHORAX

A patient with tension pneumothorax requires immediate treatment. Rapidly recurring tension pneumothorax fortunately was not common. There were 50 patients who had sufficient shift of the mediastinal structures to be diagnosed upon clinical examination. Unless the tension pneumothorax recurred rapidly it was treated by repeated thoracenteses. In most instances after two or three days the wound in the lung sealed and the pneumothorax no longer recurred. When the tension pneumothorax was sufficiently severe, there was no hesitancy in introducing a catheter between two ribs into the



3A 3B

FIG. 3.—(A) Shows a clotted hemothorax with two fluid levels. The patient ran a high fever and the culture of his original thoracentesis was positive.

(B) Open thoracostomy was not undertaken until almost six weeks after injury. The cavity measured more than 1,200 cc. This picture was taken after 17 days of continuous suction of about 150 cm. of water reduced the cavity to 50 cc. Suction was maintained until the cavity was only 5 cc. The wound healed rapidly thereafter.

pleura and sealing it under water. After four or five days, when it seemed likely that healing was underway, suction of 10 cm. negative pressure (water) was applied. This allowed for complete reëxpansion of the lung in a short time. The procedure was used in only four patients, while only one patient was brought to the hospital with a catheter in the pleural cavity. The negative pressure was maintained for about two weeks and then the catheter slowly removed to insure that the pleural space was obliterated and that the pneumothorax did not recur. Only one of these patients developed infection, and that was in the lung rather than the pleural cavity. The early reëxpansion of the lung by this method would tend to minimize the extent of the infection in the pleura, should it occur.

In only two patients did the bronchopleural fistula remain open for more than a week, thereby preventing reëxpansion of the lung by thoracentesis,

without developing an empyema. Neither of these had a tension pneumothorax. One of them did not seal his bronchopleural fistula until one month after injury, at which time his lung could be reëxpanded by thoracentesis.

SUBCUTANEOUS EMPHYSEMA

Physical examination revealed subcutaneous emphysema in 29 patients. In only two was it present to a startling degree. In both, it extended from above the eyes and ears to the back of the fingers and to the scrotum, which was blown up like a balloon. There was about two inches of air under the skin of the abdomen and thorax. The eyes were completely closed but could be temporarily opened by pressing air away from this area. The air did not extend below the upper thighs. In both instances there was a tension pneumothorax so that a catheter was introduced between two ribs within a short time after admission to the hospital. The relief of the tension pneumothorax prevented extension of the emphysema very nicely in one patient and the major part of the air was absorbed from the subcutaneous tissues in about ten days.

In the other patient the subcutaneous emphysema decreased at times, but returned with coughing. Examination showed that the bullet had perforated the trachea low in the neck before traversing the right pleura. It became apparent that as the patient coughed air was forced out of the trachea into the mediastinum and subcutaneous tissue. It seemed likely that tracheotomy would prevent the marked increase in intratracheal pressure which occurred during coughing. Thus, when the trachea was exposed and the wound was found to be situated posteriorly and in a fairly inaccessible location, a simple tracheotomy was performed. This proved to be entirely satisfactory and the subcutaneous emphysema decreased progressively thereafter.

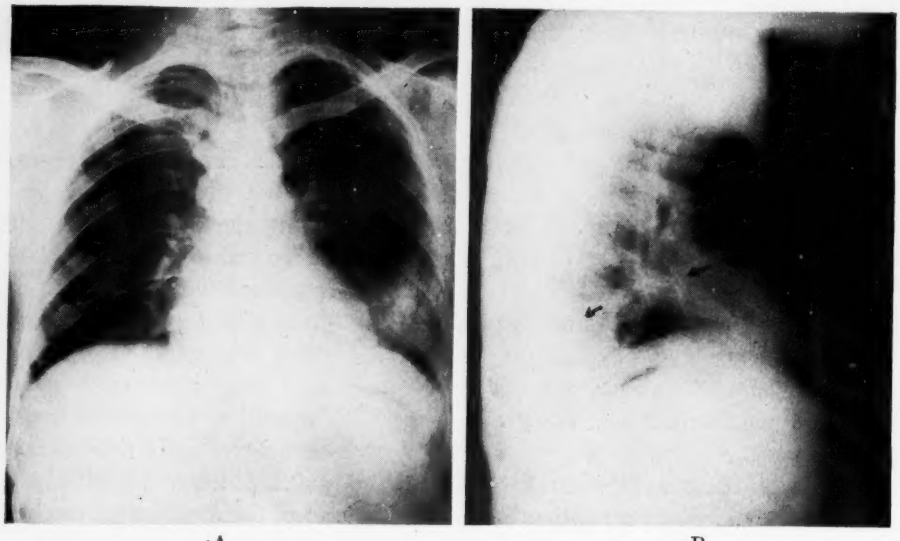
Although there were several patients in this series with some mediastinal emphysema, there was no patient in whom a wound of the mediastinal trachea or bronchus was diagnosed. The treatment usually recommended for a wound of the mediastinal trachea is to open the mediastinum through the neck, dissect down to the hole in the trachea and pack the wound open. When the wound is too low to reach in this manner, a thoracotomy with an attempt to suture the trachea has been recommended. In order for the air to go out of the trachea into the mediastinal tissues, the pressure in the trachea must be greater than that in the mediastinum. It is probable that in most instances this occurs only during coughing, for during coughing an expiratory effort is made against a closed glottis until the intratracheal pressure is very high. Then the glottis suddenly opens. By performing a simple tracheotomy the increase in intratracheal pressure is prevented. In view of the excellent result obtained in this one patient, it seems highly probable that a good proportion of tracheal wounds with mediastinal emphysema could be treated satisfactorily in this manner, using chemotherapy to prevent spreading mediastinal infection.

LUNG INJURY

More than half of the patients had little or no hemopneumothorax, as ascertained by physical examination or roentgenology. About 85 per cent of

the patients were examined roentgenologically, the first film being taken as a rule about seven to ten days after injury. The patients with simple lung damage as the result of a rifle bullet or shell fragment were treated conservatively. Usually the density in the lung shown roentgenographically cleared surprisingly rapidly and disappeared completely in three to four weeks.

In a number of instances the course of the bullet or shell fragment could be traced through the lung (Fig. 4). At times the amount of damage as seen by roentgenologic examination was surprisingly small. In three patients roentgenograms showed a healthy chest although a bullet had obviously passed directly through the lung from front to back a week, or less, before the examination.



4A 4B

FIG. 4.—A perforating rifle bullet wound of the left lung five days after injury.
(A) The A.P. view shows minimal changes.
(B) The course of the bullet through the lung can be seen in the lateral view.

It had been anticipated that as a result of trauma and hemorrhage within the lung, infection followed by a typical lung abscess might develop in some of these patients. This, however, occurred only twice, and both patients died from multiple lung abscesses.

It is probable that the prolonged fever seen in some patients with hemothorax represented simultaneous infection within the lung. Infection within the lung no doubt was relieved or obscured in some instances by drainage into a bronchus or into an empyema cavity. It was not uncommon to observe air pockets (pneumatoceles) within the damaged lung which did not go on to typical abscess formation (Fig. 5). Whatever the incidence of infection within the wound of the lung itself, it became a recognizable major factor in very few instances.

EMPYEMA

Principles and Methods of Treatment.—The fundamental objectives in the treatment of empyema are to obtain adequate drainage and to achieve the

reëxpansion of the lung as rapidly as possible. Repeated thoracenteses and closed drainage through a catheter introduced into the pleural cavity are the two methods commonly employed early in the disease. Unfortunately, there is usually sufficient exudate to prevent adequate and complete drainage by either of these methods. On the other hand, early open drainage to remove this exudate allows the lung to collapse and is the procedure which accounted for a considerable part of the mortality from empyema in World War I. For

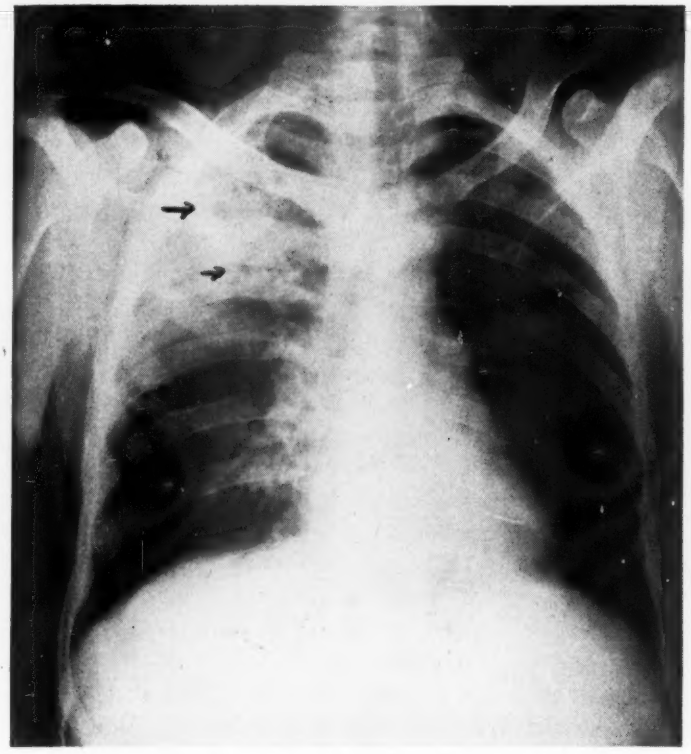


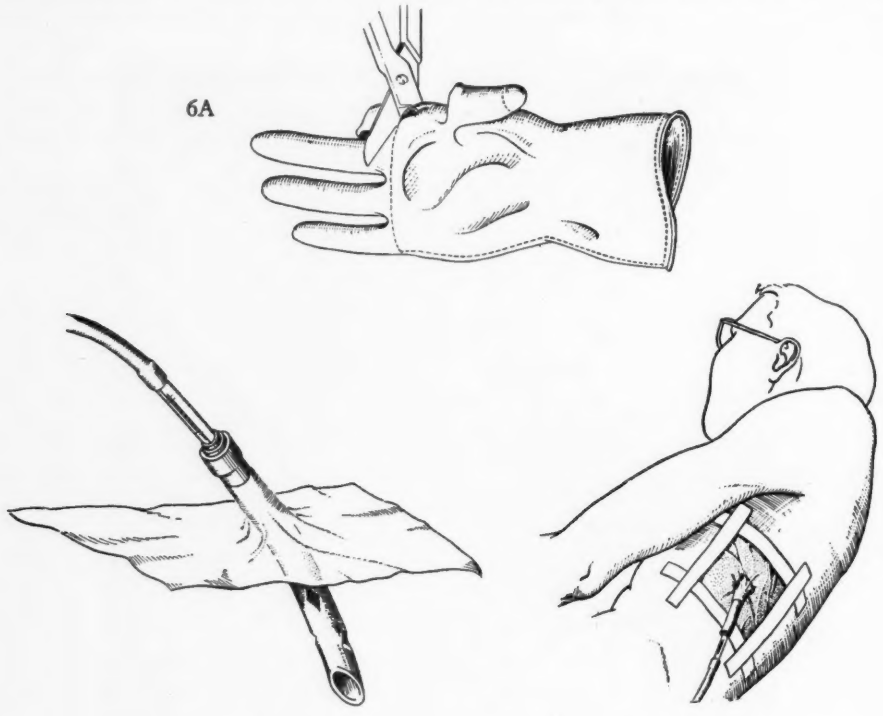
FIG. 5.—A perforating shell fragment wound of the right lung showing considerable lung damage with cavity formation. The picture was taken eight days after injury. The patient had little or no fever. Healing occurred uneventfully.

this reason either repeated thoracenteses or closed drainage is usually advocated to reduce the size of the empyema cavity as much as possible until the lung has become adherent and open drainage is a safe procedure.

Closed drainage has the advantage over open drainage in that it exerts a negative pressure and produces a more rapid reëxpansion of the lung. However, the interib catheter frequently becomes plugged resulting in ineffective drainage. It is highly desirable to use a method by which the exudate can be removed from the empyema cavity and at the same time allow for closed drainage with the use of negative pressure postoperatively. The conversion of an open empyema into a closed one by an air-tight seal so as to rapidly reëxpand the lung by a high degree of negative pressure is certainly not new.

However, a satisfactory method of applying an air-tight seal may not be familiar to all. Such a method was used in this series of patients and was found to be most satisfactory.

Open drainage was done through a large opening by the removal of segments of two ribs and the intervening muscular bundle. This allowed for the complete removal of the exudate. A three-quarter-inch rubber tube,



Method of Applying Suction to an Open Thoracostomy

FIG. 6.—(A) The fingers but not the thumb are cut from a rubber glove. The tip of the thumb is cut away. The glove is then cut along the ulnar aspect. This will then open to form a sheet of rubber tissue with the thumb in the center.

(B) A large rubber tube is then put through the thumb and glued to it. The tube is connected with an ordinary three-bottle Wangensteen suction apparatus.

(C) The skin around the empyema opening is painted with the glue used with the Padgett dermatone for removing skin grafts. A little gauze packing is placed around the tube to absorb any excessive fluid until the rubber tissue is stuck. The rubber tissue is then held moderately taut and placed down smoothly on the skin surface. The tube must already be connected to the suction apparatus so that suction can be applied immediately. This will pull the rubber tissue tightly against the skin surface so that it may become effectively glued. The edges of the rubber tissue are covered with adhesive. When carefully applied this air-tight seal is effective for 10 to 14 days. With the Wangensteen suction apparatus a negative pressure of up to 150 cm. of water can easily be attained.

with several holes in the sides, was used to insure adequate drainage. An air-tight seal was made to the chest wall by the method shown in the accompanying diagram (Fig. 6). This gave a satisfactory closure, which usually held for about two weeks. It was felt that a high degree of negative pressure

was desirable to insure rapid reëxpansion of the lung. The ordinary three-bottle Wangensteen suction apparatus was quite satisfactory for this purpose and gave about 150 cm. of negative pressure (water). When the seal was tight, and the apparatus did not leak, the water in the bottles had to be changed very infrequently. An incidental advantage to this method of treatment was that the frequent dressings usually required by an empyema were avoided.

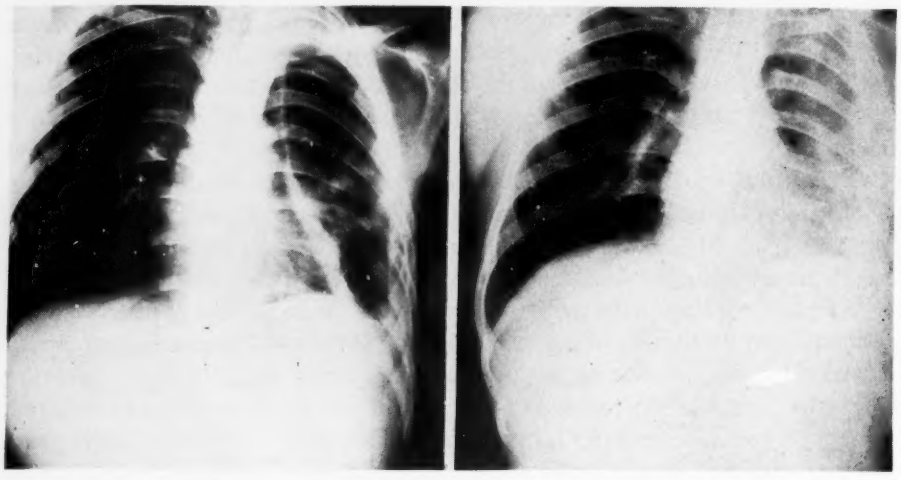
During the early part of the campaign repeated thoracenteses were employed until the lung had become fixed and the open drainage with the complete removal of the exudate could be done under local anesthesia. It was then converted to closed drainage by the air-tight seal and a high degree of negative pressure applied. This air-tight seal proved to be so satisfactory and reliable that during the latter part of the campaign the open drainage with removal of the exudate was undertaken early (7–14 days), under endotracheal anesthesia. This offered the advantage that the layer of fibrous tissue over the lung was still quite thin, so that the lung could be reëxpanded more rapidly.

Decortication of the lung, as practiced in the Mediterranean Theater, was undertaken only once (the most recent case) in this series of empyemas. By complete removal of the exudate is meant the removal of all the exudate that can be removed by the hand and a sponge. At this point, the lung could not be completely reëxpanded with positive pressure anesthesia, because of the residual layer of fibrous tissue over the lung surface. The subsequent application of an high degree of negative pressure (150 cm. of water) did bring about the complete reëxpansion of the lung unless the empyema was very old. By decortication is meant the removal of the layer of fibrous tissue from the lung surface after removal of the exudate in the pleural cavity. After its removal in the one patient, the lung could be completely inflated by positive pressure from the anesthesia apparatus.

Early thoracostomy with complete removal of the exudate followed by the use of an high degree of negative pressure has been most satisfactory in producing the rapid and complete reëxpansion of the lung. The experience with only one case of decortication in empyema does not allow for a proper evaluation of the procedure, but it would certainly seem to be an additional aid in reducing the residual thickening of the pleura in those cases in which it can be done. Churchill[1] points out that after about six weeks the fibrous layer becomes sufficiently organized so that it can not be removed from the lung. The high degree of negative pressure as used in this series is especially valuable when decortication of the lung is not or cannot be done. Because of the degree of suction, there is usually some blood mixed with the drainage for the first few days. The rapidity of the reëxpansion of the lung depended upon the duration of the empyema before the suction was applied. The temptation to remove the suction when the cavity has been reduced to 20–50 cc. should be avoided. Especially in old empyemata the obliteration of this residual cavity may take considerable time because of the thickness of the pleura at the outset. When the suction was removed too soon, the cavity instead of getting progressively smaller frequently increased in size. It was

found to be best to maintain the suction continuously. The large tube was replaced by a small one and the suction maintained until the cavity measured less than five cubic centimeters.

When, because of the extent of the wound to the lung in an early case, we were fearful of sudden complete reëxpansion of the lung, only about ten centimeters of water negative pressure was applied. This was obtained by the water suction apparatus commonly used following lobectomy or pneumonectomy with drainage.[2] This type of apparatus was also necessary in cases where there was a small bronchopleural fistula, since the water would flow through the Wangensteen apparatus too rapidly.



7A 7B

FIG. 7.—(A) This film was taken about two months following the original wound. The lung is almost completely collapsed.

(B) In spite of the delay in applying suction, the lung was completely reëxpanded and the empyema cavity was obliterated. There was considerable residual thickening of the pleura.

TYPES OF EMPYEMA ENCOUNTERED

There were 30 patients who developed empyema, giving an incidence of 9.7 per cent. Empyema developed in 5 per cent of bullet wounds, 10 per cent of shell fragment wounds, and 66 per cent of bayonet wounds (six patients). The common organisms found were *hemolytic Staphylococcus aureus, nonhemolytic Streptococcus,* and *Streptococcus viridans.* The fact that in not a single instance was the *hemolytic Streptococcus* found upon culture would seem to be ample proof of the value of sulfonamides in this series of patients.

We had the unusual experience of obtaining a pure culture of organisms of the *Salmonella* group from the hemothoraces of three patients. They all had considerable fever. Two of these could not be completely aspirated by thoracentesis and came to open drainage. The third could be aspirated almost completely and did not develop an empyema.

Four general types of empyema were encountered in this series. They will be discussed separately.

Type 1.—Infection in a Simple Hemothorax: The common type of empyema occurred in the liquid hemothorax which became infected with an organism of relatively low virulence. There were 16 patients with this type of empyema. Early in the course of their disease these patients looked very little different than those with simple hemothorax except that they invariably ran considerable fever. Upon the initial thoracentesis the blood usually looked uninfected but, as noted above, the cultures were positive with few exceptions. During the early part of the campaign especially, these patients were treated by repeated thoracenteses until the lung became adherent and open drainage could be undertaken. When repeated thoracentesis was effective the empyema cavity was small when the patient came to open drainage. However, there was frequently sufficient thick exudate to prevent anywhere near complete aspiration by thoracentesis. During the latter part of the campaign these patients were operated upon early and the exudate evacuated, under endotracheal anesthesia without waiting for fixation of the mediastinum. With the use of an high degree of negative pressure following an air-tight seal rapid reëxpansion of the lung was obtained.

Type 2.—Infection in a Clotted Hemothorax: Eight patients with clotted hemothoraces developed infection. In these there was extensive clotting and the development of multiple cystic collections of fluid which did not communicate freely with one another. In five there was at least some communication, for the initial thoracentesis gave a positive culture, and at operation the fluid in all the cystic cavities appeared infected. In the early part of the campaign operation upon the patients was delayed until there was fixation of the mediastinum. In the latter part of the campaign operation was undertaken early (7–14 days), under endotracheal anesthesia. A large opening was made, the clot completely evacuated (decortication was done in the most recent case), and suction applied. Excellent results were obtained in all. The earlier the operation was done, the less was the residual thickening of the pleura. The high degree of suction (150 cm. of water) was especially helpful in the delayed cases. One patient had a cavity containing over 1,200 cc. when suction was applied six weeks after his original injury. After 17 days of continuous suction the cavity contained only 50 cc. (Fig. 3).

The remaining three patients were received early in the campaign. The multiple cystic collections did not communicate. At operation, some appeared infected and others did not. Cultures of the original thoracenteses were negative because the infected pocket was not aspirated. Considerable time was lost in waiting to obtain pus upon aspiration. At operation, when the exudate was removed, it almost appeared as if the lung had been removed. Nevertheless, complete reëxpansion of the lung was obtained by an high degree of suction.

Type 3.—Putrid Empyema: Three patients were admitted to the hospital with putrid empyema. They were desperately sick. The gross character of the fluid obtained by thoracentesis left no doubt as to the diagnosis. These patients differed from those of Type 1 chiefly in the virulence of their infection and the urgency of their treatment. They were subjected to emergency

operation six, seven and 11 days after injury. Large shell fragments were removed from two. A three-quarter-inch rubber tube was inserted, fixed with an air-tight seal and suction applied.

Type 4.—Infected Open Sucking Wounds: Three patients were admitted to the hospital with infected open sucking wounds. The urgency of their treatment was apparent but complicated by the inability to suture the wound. They were desperately sick due to the disturbance in the mechanism of respiration, in addition to the infection. Two of these patients were treated by inserting the drainage tube directly into the pleural cavity through the sucking wound and fixing it with an air-tight seal. In the third patient the open wound was high on the back so that it was sealed by covering with a sheet of rubber tissue glued to the skin. The suction was applied through a tube inserted in the midaxillary line (Fig. 8).

Results in Empyema: There were no deaths in the group of 30 patients with empyema. One never anticipates a death in a localized empyema. However, a considerable part of the mortality from empyema in World War I was due to rapidly spreading infection. It would seem that the routine use of sulfonamides in this series was an important factor in preventing spreading infection and in avoiding any deaths in this group.

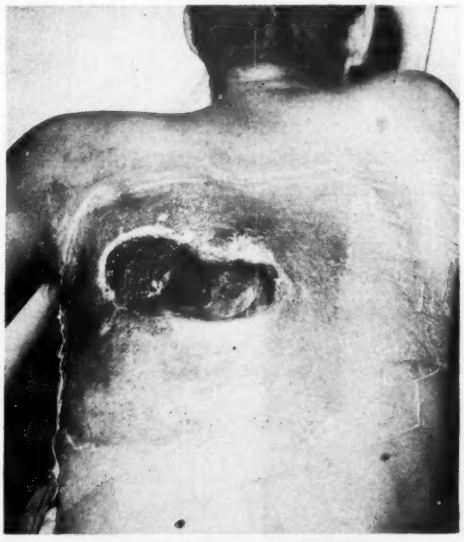
Complete reëxpansion of the lung was obtained in all but two patients. Both of these had large hemopneumothoraces and, unfortunately, were treated conservatively. In each instance the initial fever almost completely subsided and the patients were apparently doing satisfactorily. Late in the course of the disease high fever appeared again. Investigation revealed an empyema incident to an old infection in the lung rupturing into the hemothorax. This was demonstrated at operation. When suction was applied after operation, the lung in both patients had been collapsed to a considerable degree for over two months and was covered by a thick layer of fibrous tissue. Nevertheless by the use of a high degree of negative pressure (150 cm. of water) their cavities were reduced to 15 and 50 cc. An unroofing (Schede) operation was successful in closing the remaining cavity in both patients.

FOREIGN BODIES IN THE THORACIC CAVITY

In the majority of wounds the missile traversed the thoracic cavity. In only 61 patients (20 per cent of this series) was a foreign body found to be in the thoracic cavity. Although the thoracic wounds were due equally to bullets and shell fragments, in only seven instances did a bullet remain in the thoracic cavity, as compared to 54 shell fragments.

It was of some interest to determine the influence of the retained foreign body upon the course of the wound. The incidence of hemothorax as opposed to simple lung trauma was the same, whether the missile traversed the chest cavity or stopped in it. Neither was there a significant difference in the incidence of empyema.

It had been anticipated that infection would occur in the lung around the retained foreign body and that a typical putrid lung abscess might develop. In no instance was this definitely demonstrated. In a number of patients



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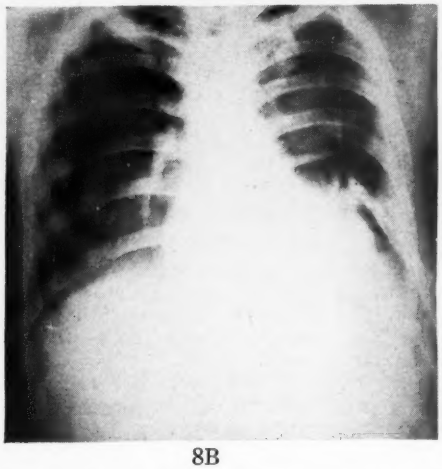

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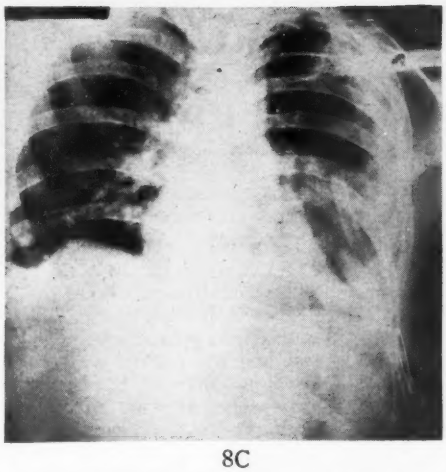

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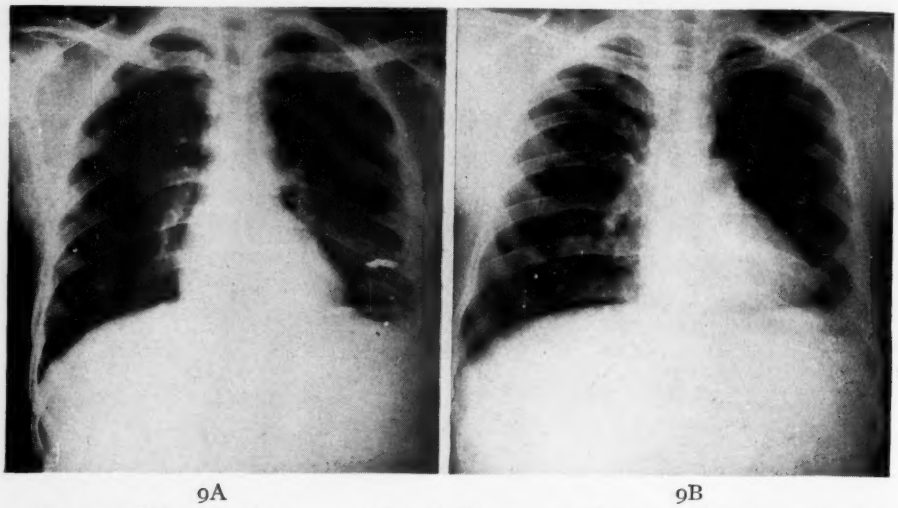
FIG. 8.—(A) This picture was taken three weeks after this patient was admitted with an open sucking infected wound. Clostridium welchii infection was present. Suture of the wound was out of the question. After cutting away the dead tissue, the wound was sealed by packing with gauze lightly and sealing it by gluing a sheet of rubber tissue over it to the skin. An interib catheter was previously inserted and attached to continuous suction so that the negative pressure would pull the rubber tissue down against the skin and make an effective seal. At this time the lung had become almost completely reëxpanded and fixed to the parietal pleura.

(B) Roentgenograms taken soon after insertion of the interib catheter, when only 10 cm. of water negative pressure was applied.

(C) After a few days the suction was increased to 150 cm. (water) negative pressure. Within a month of the time he was injured the lung had been reëxpanded and the cavity was only the size of the tube.

it was demonstrated that an infected cavity was present around the foreign body but it drained into the bronchus or the pleural cavity, so that a typical lung abscess did not occur. In three patients there was putrid empyema early in the disease which possibly may have developed on this basis. In one case an abscess around a foreign body obviously ruptured into the pleura to give an empyema when a pneumohemothorax had previously been present.

The patients who had large foreign bodies in the lung usually had some persistent cough with the expectoration of some mucoid material. Three of the patients had persistent sinuses which healed only after the removal of the foreign bodies. Only one patient had a massive pulmonary hemorrhage (Fig. 9). This occurred about two months after injury at a time when he



9A 9B

FIG. 9.—(A) This picture was taken about a month after the original wound. The hemopneumothorax had responded to thoracentesis. A sinus persisted at the site of the wound of entrance in the left midaxillary line. While hoping for this sinus to close the patient had a massive pulmonary hemorrhage. This was about two months after the original injury, and the patient was otherwise perfectly well.

(B) Two days following the hemorrhage the fragment was removed. The cavity in the lung was packed for fear of further bleeding. The drain was out in two weeks. Within a month the lung had cleared. The patient returned to duty.

was well except for a persistent sinus and cough, and was awaiting operation. The foreign body was removed two days later, with an uneventful recovery. The patients with small foreign bodies were usually asymptomatic.

A metallic foreign body which becomes encysted in the lung is in the center of a granulating cavity. It seemed likely that sooner or later a number of the larger and more irregular foreign bodies would be associated with infection or hemorrhage. It is impossible to say which foreign body is likely to cause trouble. For this reason an arbitrary standard was set of 1 to 1.5 cm. All foreign bodies over that were to be removed and all under that were to be left alone. With a few exceptions this policy was followed.

Five of the foreign bodies stopped in the mediastinum. Only one appeared to be in close proximity to a large vessel, and was removed. The other four

seemed no more likely to cause trouble than metallic fragments elsewhere in soft tissue. They were observed for a month before return to duty.

REMOVAL OF FOREIGN BODIES

Twenty-three of the 61 patients with retained foreign bodies in the thoracic cavity were subjected to operative removal of the foreign bodies. Two were operated upon as emergencies because of putrid empyema. One was removed from the pericardial sac because of effusion with tamponade and cardiac failure. One was removed from the free pleural cavity because of persistent effusion. One was removed from the mediastinum. The remaining 18 were removed from the lung as more or less elective procedures.

The patients were allowed to recover as completely as possible from their wounds before removal of the foreign bodies. In those who had no hemothorax the operation was usually undertaken from three to four weeks after injury. Those who had hemothoraces were treated by thoracentesis and allowed to recover from it before the foreign body was removed, four to eight weeks after injury. There seemed to be no reason for doing this elective operation before the patient was in the best possible condition.

The removal of the foreign bodies was found to be simpler than anticipated. No serious difficulty was encountered in any of these patients, and there were no deaths in this group. A very important point was proper localization of the foreign body. In addition to obtaining anteroposterior and true lateral roentgenograms, the patients were examined under the fluoroscope and the point marked at which the foreign body was nearest the skin.

The patients were operated upon under endotracheal anesthesia, with controlled respirations. An intercostal incision was used. There were usually adhesions present, especially when there had been an hemothorax. The general area of the site of the foreign body could be ascertained by the indurated mass in the lung. It was frequently necessary to free the lung considerably in order to feel this. In any event the lung was always freed sufficiently so that the involved area could be compressed between the fingers in the event that troublesome bleeding was encountered upon incising the lung. The bleeding was minimized if the incision could be made through the scar of the wound of entrance into the lung. The freed lung containing the indurated area was then taken between the fingers and a 22-gauge needle was inserted to locate the foreign body exactly. The lung was then cut open and the foreign body removed. The greatest care had to be exercised when the foreign body was near the hilum of the lung for fear of cutting one of the large vessels (Fig. 10).

In about one-half the patients the cavity in the lung appeared to be clean, so that the opening in the lung was sutured and the chest closed without drainage. In the other half a drain was used because there was some purulent material around the foreign body. When hemorrhage from the cavity was feared, dry gauze was inserted into it and brought out alongside of the drainage tube in the pleura.

Oral prophylactic sulfonamide therapy was administered routinely both pre- and postoperatively. Penicillin was available for use only in the last

part of the campaign. Spreading infection did not occur in any instance, and the tubes were all out within two weeks. In one patient a pure culture of *Clostridium welchii* was obtained from the cavity around the foreign body. The wound was drained and no trouble encountered. There were almost no complications. Two patients had sufficient bronchial secretion to require tracheal aspiration because of atelectasis. Two patients had small stitch abscesses, but no patient developed infection in the lung or pleura.

The roentgenographic appearance in these patients cleared completely (Figs. 9, 10 and 11), and they apparently had excellent results. All of these patients returned to duty.

WOUNDS OF THE HEART AND PERICARDIUM

Only four patients in this series had recognizable wounds of the heart or pericardium. One was admitted 12 hours after a 25-caliber bullet perforated his left ventricle, left lung, and spleen. At operation, the perforation of his heart was sutured and the spleen removed, but he died 48 hours later.

One patient with a large right hemothorax had the shell fragment lodged in the pericardial sac behind the heart. He developed marked signs of cardiac failure three weeks after his injury, incident to slow tamponade. The foreign body was removed. The pericardial collection was sterile. He made a rapid and uneventful recovery.

The other two patients were operated upon also. One for a purulent pericarditis following a bayonet wound. The other had a pericarditis following a shell fragment perforation of the tip of the heart but probably not of the cardiac cavity. Both of these patients recovered.

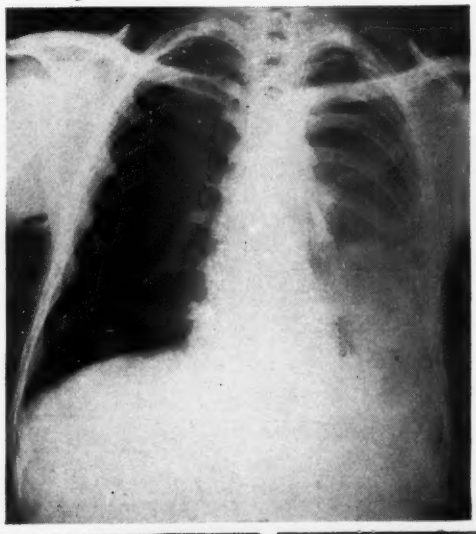
THORACO-ABDOMINAL WOUNDS

There were 46 patients with thoraco-abdominal wounds. In some instances this was a single wound which traversed the diaphragm while in others there were multiple wounds involving both the chest and abdomen. In this group there were nine deaths, a mortality of 20 per cent. Only one of these patients died from the chest wound. The remaining eight patients died of peritonitis, or complications of it.

The patients with wounds in the right side, where the liver was the only abdominal organ involved, did very well. In two patients, operated upon at the portable surgical hospitals, the diaphragm was sutured to the chest wall above a low penetrating wound of the right chest in order to close the pleural cavity. They did well.

MORTALITY

The total number of deaths in this series of 308 patients, regardless of the associated injuries or diseases, and regardless of the cause of death, was 23, a mortality of 7.4 per cent. Twelve of these had insignificant chest wounds and died of major abdominal or cerebrospinal wounds. Five of the patients obviously died of associated injuries or diseases, although in some the chest wound may have contributed to the patients' general poor condition. Only six patients, 2 per cent of the total series, died primarily of their chest wounds.



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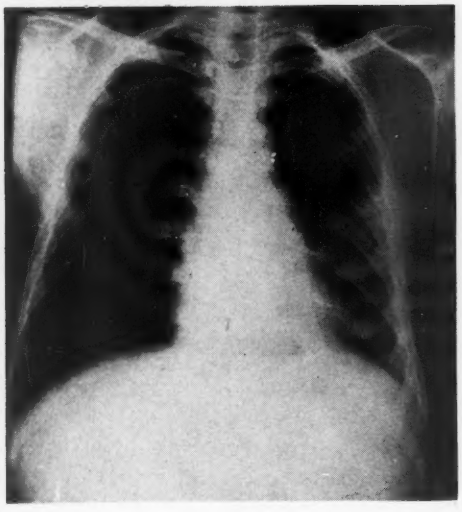

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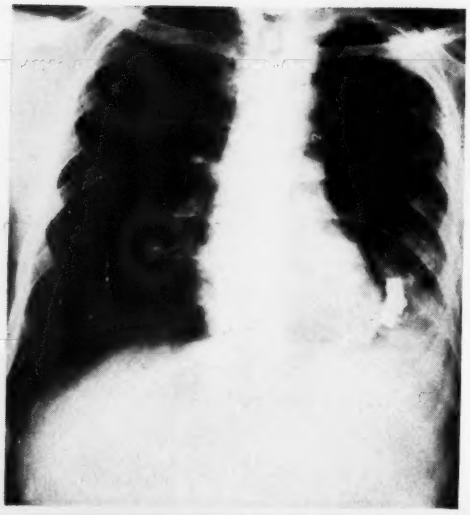
FIG. 10.—(A and B) A 25-cal. rifle bullet entered through the sternum and lodged in the hilum of the left upper lobe. As shown in the lateral view there was some atelectasis of the lower lobe. This cleared with bronchial aspiration. Later, detailed roentgenograms showed some cavity around the bullet. The patient had a cough productive of mucus but ran no fever.

(C) The bullet was removed as an elective procedure two months after injury. An intercostal incision was used. The bullet was removed from between the branches of the artery to the upper lobe. The patient had an almost perfect result, and returned to duty.



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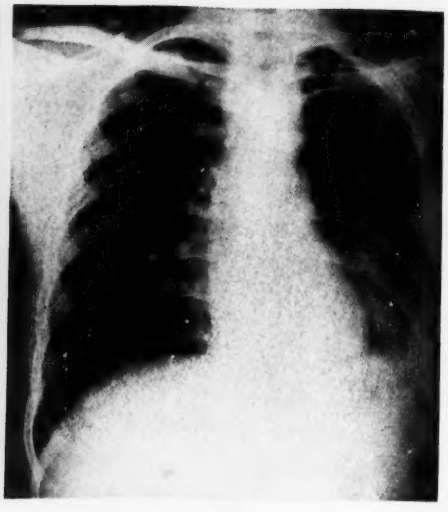

11C

FIG. 11.—(A and B) These pictures were taken one month after the patient was wounded. He had recovered uneventfully from an hemopneumothorax treated by repeated thoracenteses. A high fever at the outset had subsided.

(C) At operation, purulent material was found around the shell fragment. A pure culture of *Clostridium welchii* was obtained. The lung was drained. The convalescence was uneventful except for about four days of fever. This film, taken one month after operation, shows complete clearing of the lung. He returned to duty.

At the beginning of this campaign it was felt that if a patient with a wound of the thoracic cavity survived to reach this hospital, he should not die of his chest wound unless he developed overwhelming pulmonary infection or had some unusual accident. It seemed reasonable to hope that with adequate treatment no patient should die from a disturbance of his respiratory mechanism and that by careful watching and timely intervention no patient should die of empyema. These ambitions were not quite realized.

Of the six patients who died primarily of their chest wounds, one did die of a disturbance of his respiratory mechanism. He was first seen 48 hours after injury. His wound was still sucking. He had suffered for 48 hours from inadequate aeration and an inability to cough up the blood and mucus in his lungs. In spite of reëxpansion of the lung by the insertion of a catheter with suction, tracheal aspiration, and transfusion, he died within three hours. The second patient died from the perforating wound of the heart, lung and spleen. The third died from a cerebral air embolus, proved at autopsy, incident to an insignificant wound of the lung. The fourth was also believed to have died of a cerebral air embolus, but no autopsy was done. The remaining two died of multiple lung abscesses.

Discussion.—Once the patient with a wound of the thoracic cavity is over the immediate threat to life from blood loss or altered respiratory physiology, the chief objective in treatment should be the complete restoration of function. During the observation and treatment of this series of patients it became increasingly apparent that the most important factor in the complete restoration of function was the early reëxpansion of the lung in the patients with pneumohemothorax or empyema. On the basis of the experience with this group of patients, it seems evident, that early thoracentesis is the treatment of choice for the patient with hemopneumothorax.

A few patients whose hemothoraces could not be aspirated by thoracentesis because of clotting were treated conservatively early in the campaign. This was a mistake. Open operation with evacuation of the blood clot and decortication of the lung is certainly the treatment of choice.

As experience was gained during the course of this campaign it became increasingly apparent that unless an empyema was small, the best result was obtained by early operation, under endotracheal anesthesia, without waiting for fixation of the mediastinum, evacuation of all exudate, and rapid reëxpansion of the lung by the application of an high degree of negative pressure.

CONCLUSIONS

1. A series of 308 patients with battle wounds of the thoracic cavity were admitted to a General Hospital during a period of 16 months. This was an unusual opportunity, in that the patients were evacuated to this hospital as rapidly as the circumstances of the campaign would permit (over 50 per cent within 36 hours), and that, with few exceptions, they were treated in this hospital until they had completely recovered.

2. The personnel of the Portable Surgical Hospitals who operated upon

these patients early, under the most trying conditions of jungle warfare, are responsible, to no small degree, for the excellent results.

3. The total mortality in this series, regardless of the associated injuries or diseases, was 7.4 per cent. In only 2 per cent (six patients) could the death be attributed to the chest wound.

4. The treatment of choice for hemopneumothorax is the rapid reëxpansion of the lung by repeated thoracenteses. When the hemothorax is clotted (8 per cent of hemothoraces in this series) thoracentesis is not effective. In the presence of this complication thoracostomy, with evacuation of the blood clot and decortication of the lung, is the most effective method of bringing about rapid reëxpansion of the lung and complete restoration of function.

5. Simple tracheotomy is suggested as a treatment for wounds of the trachea with mediastinal and subcutaneous emphysema. It is probable that by eliminating the tremendous increase in intratracheal pressure during coughing, the forcing of air into the mediastinum will be stopped in most instances.

6. The incidence of empyema was 9.7 per cent (30 patients). Infection within the lung was a major problem in only two patients. The early and routine use of sulfonamides probably played an important part in almost eliminating serious spreading infection. Penicillin was not available for prophylactic use in these patients.

7. The primary objective in the treatment of an empyema should be the early and complete reëxpansion of the lung. A method of treatment is described. A large opening was made in the chest and the fibrous exudate completely removed. By means of an air-tight seal this was then converted into closed drainage. The application of an high degree of negative pressure (150 cm. of water) was very helpful in bringing about the rapid reëxpansion of the lung. Especially in the presence of a large empyema, it is recommended that this be done early, using positive pressure anesthesia, without waiting for the fixation of the mediastinum.

8. Twenty-three of 61 foreign bodies retained in the thoracic cavity were removed. The technic used is described. The simplicity of the procedure and the excellent results obtained in this series, suggests the routine removal of large foreign bodies from the lung. It is recommended that when undertaken as an elective procedure, the patient should be allowed to recover from his wound as completely as possible before being operated upon for the removal of the foreign body.

REFERENCES

[1] Churchill, E. D.: The Surgical Management of the Wounded in the Mediterranean Theater at the Time of the Fall of Rome. ANNALS OF SURGERY, **120**, 268, 1944.

[2] Johnson, J.: Total Pneumonectomy. Surg., Gynec. & Obst., **76**, 460, 1943.

THE "WET LUNG" IN WAR CASUALTIES

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EXPERIENCE gained in treating a large number of casualties in the Sicilian and Italian campaigns prior to July 1944, has shown the importance of the "wet lung" in reference to the morbidity and mortality of patients with wounds of the chest, brain and abdomen. The authors' combined experience consisted in the management of over 770 casualties in which the chest wound was the primary concern as well as the thoracic complications that arose in over 3,000 other casualties of all types. These cases were treated both in forward surgical installations as well as in a Base Hospital designated as a Thoracic Surgical Center in the North African Theater of Operations (NATOUSA). (We have found no reference in the literature prior to the studies now in publication from this group.) Because of the importance of wet lung in war casualties, it seems desirable that a thorough discussion be presented at this time.

DEFINITION

In handling this large number of casualties it was found in the Forward Hospitals in particular, that those cases with dry lungs gave us very little trouble. On the other hand, those showing a wet pulmonary tree were difficult to resuscitate from shock. They were poor operative risks for emergency surgery and most frequently developed pulmonary complications. In the chest wounds the mortality was highest in this group. In fact, no more serious problem was encountered by the surgeons in Forward Hospitals treating thoracic wounds than the therapeutic problem of the wet lung. Gradually we realized that it was necessary to pay more and more attention to this type of patient. This concept of the wet lung developed after a year's study of the problem. By wet lung is meant the persistence of fluid in the pulmonary tree. This fluid may be present in various forms—mucus, blood, serum, *etc.* The forces which favor the persistence of moisture in the pulmonary tree are mainly the results of trauma. The presence of fluid in the bronchial tree is of most importance early, as it promotes anoxia, and late, as it paves the way for subsequent pulmonary complications.

CAUSATIVE FACTORS

There are two groups of factors which are important in the development of wet lung: 1. Forces leading to the production of secretions and other fluids in abnormal amounts in the respiratory tract. 2. Conditions preventing adequate removal of the fluids so produced. In war casualties many conditions

are present which favor both the accumulation and inadequate expulsion of fluid material from the pulmonary tree.

Mucoid secretions may be present in abnormal amounts in the bronchial tree as a result of increased secretory activity of the bronchial mucosa. This has been observed clinically in many battle casualties. Experimentally, de Takats, and his associates,[1] have shown that any appreciable trauma to the chest wall was followed almost immediately by widespread bronchial spasm and increased bronchial secretion in 60 per cent of the animals tested. Abdominal stimuli, such as traction on the cystic duct or mesentery, produced similar bronchial findings. Just how long this bronchial secretion and associated spasm continues is not definitely known. Clinically, we have observed wet lung for several days following injury, although other factors producing "moisture" in the pulmonary tree were undoubtedly present.

Blood from intrapulmonary hemorrhage is present in the bronchial tree in varying amounts and may cause bronchial obstruction. Clinically blood appears to be irritating to the bronchial mucosa and causes increased bronchial secretion. Mucopurulent secretions from upper respiratory infections and bronchitis are not uncommonly present in the bronchi of soldiers undergoing the exposure of combat conditions. Bloody fluid from an hemothorax may also be present in the bronchial tree as a result of spillover through a bronchial fistula.

Fluid arising in the alveoli of the lung also produces obstruction of the pulmonary air-way and presents a difficult clinical problem. The mechanism of production of pulmonary transudates and exudates in the severely injured is not well understood. Some of the factors are known and will be briefly enumerated. It is generally established that there is local extravasation of plasma at the site of injury following trauma. Thus, damage to pulmonary tissue would result in the leakage of plasma as well as blood into the alveoli in the injured portion of the lung. The experimental work of Drinker and Warren[2] has shown that tracheal obstruction produces pulmonary and pleural transudates and exudates containing red blood cells. Severe respiratory movements were similarly found to lead to the formation of pulmonary transudates. Their studies further showed that anoxia was a potent factor in altering the permeability of the pulmonary capillaries resulting in the leakage of plasma fluid. Thus, early there are four known factors which have an important bearing on the escape of fluid from the pulmonary capillaries into the alveoli and bronchial radicles: (1) Pulmonary trauma; (2) increased respiratory effort; (3) tracheal obstruction; and (4) anoxia. Blast injuries of the lung are known to produce hemorrhage in the terminal divisions of the pulmonary tree and may present important additional factors in the production of alveolar transudates. In the late stages of shock the capillary permeability is increased in nontraumatized regions of the body so that blood plasma escapes into the tissue spaces. That which escapes into the pulmonary alveoli results in the clinical findings of pulmonary edema. The clinical significance

of the interaction of these conditions which are present in severely injured patients, especially those with thoracic trauma, will be discussed later.

In order to understand the factors leading to inadequate expulsion of fluids formed in the pulmonary tree, one must analyze the normal cough mechanism. There are four main factors. First, there is the voluntary drawing in of air into the lungs of the conscious patient by raising the ribs and lowering the diaphragm. The breath is then momentarily held by closing the glottis. The abdominal muscles are tensed, the intercostal spaces are narrowed, and the diaphragm relaxed to give the expulsive force. The sudden opening of the glottis results in releasing the bechic blast necessary to raise the sputum. Chest pain arising in the chest wall or pleura prevents both expansion and forceful contraction of the thorax. This potent factor in preventing successful cough is present in varying degrees in thoracic injuries. In the same way, wounds causing abdominal pain prevent the tensing of the abdominal muscles necessary for effective cough. When the diaphragm is acutely injured or pushed up by distended intestines or a dilated stomach, the piston-like action is impaired and cough is ineffectual.

Rib fractures are frequently the source of severe thoracic pain when cough or deep breathing is attempted. However, when there are multiple fractures of ribs or sternum resulting in a so-called "flail chest" the added factor of the paradoxically moving chest wall is present. On inspiration the chest wall falls in, due to the negative intrathoracic pressure, while on expiration the thoracic cage moves out. Attempts at coughing exaggerate the paradoxical movement of the chest wall, and the resultant cough is very ineffectual. Because of severe pain experienced with fractured ribs and "flail chest," oversedation with morphine is not uncommon. The standard army "syrette" of morphine tartarate is put up in 0.5 grain tubes. Not rarely a patient with a "flail chest" or other severely painful thoracic or abdominal wound arrived in the Field or Evacuation Hospital shock ward in a semicoma with cyanosis and infrequent respirations, the direct result of the reception of two full syrettes of morphine (1 gr.) in the space of a few hours. This is partly due to the dyspnea and anxiety of the patient, who calls for more sedation, and also because the recording of every medication on the field medical record is sometimes very difficult under field conditions. The patient may receive a second injection of morphine because there is no record of the first. Shock officers of the Field and Evacuation Hospitals must be constantly on guard to avoid overdosage with morphine of the recently admitted patient, who may be apprehensive as the result of anoxia and is anxious and upset by the ambulance ride. Oversedation with opiates for any type of wound leads to a decrease in the cough reflex and promotes the accumulation of secretions in the bronchial tree.

In a like manner skull wounds producing coma and the unconsciousness resulting from shock permit the pooling of fluid in the bronchi. The prolonged administration of anesthesia to those in poor condition, followed by delayed reactivity of the patient, may lead to the retention of bronchial secre-

tions, and postoperative pulmonary complications are prone to develop. Upper respiratory infections were common among soldiers living under field conditions during the winter months of the 1943-44 Italian Campaign. This was aggravated by the exposure accompanying their litter-carry down from the mountain tops. Frequently 6-12 relays of litter carries were necessary to get the wounded men down to the Collecting Station, a trip often consuming 12 hours. Because of pain experienced in movement, the wounded man tends to lie constantly in one position, which promotes the gravitation and retention of secretions in the dependent portions of the lung.

HARMFUL EFFECTS

(A) *Early.*—The presence of fluid in the respiratory tract of the acutely injured patient has an important bearing on his state of shock and recovery therefrom. We have considered how blood, mucoid secretions, aspirated material, and transudates may be present in the pulmonary tree. The presence of this obstructing matter prevents adequate intake of oxygen to the alveoli. This results in less oxygen being available for the pulmonary capillary and "anoxic" anoxia results. According to the work of Drinker and Warren[2] anoxia increases capillary permeability and, therefore, more plasma tends to be lost into the tissues. Fluid from the pulmonary capillaries extravasated into the alveoli again decreases the oxygen available for the blood stream. In the advanced state, we have a clinical picture which cannot be differentiated from pulmonary edema seen in other conditions. Thus, the persistence of fluid substances in the pulmonary tree aids in the establishment of a vicious cycle that tends to increase the degree of the shock. We have seen shock unrelieved by the standard measures of "replacement therapy" with blood and plasma until the treatment of the wet pulmonary tree brought the patient out of his extremely precarious condition. If sufficient attention is not paid to the wet lung with its resulting anoxia, serious changes in other organs will take place. Most sensitive is the central nervous system, where severe cerebral anoxia over a short period of time may result in marked cortical impairment. Psychotic manifestations and coma which were, in the main, caused by cerebral anoxia were occasionally seen in our series of cases.

Plugging of a branch bronchus allows no exchange of gases in the lobule supplied by this bronchial division. With the absorption of the oxygen by the pulmonary capillaries "lobular atelectasis" may be produced. Of course, complete plugging of a branch bronchus to a lobe or stem bronchus to one lung would increase the anoxia and shock, not only due to the decrease in the alveolar bed available for the absorption of oxygen, but also to the associated mediastinal shift.

(B) *Late.*—If the patient is not too severely wounded, he may recover from the primary shock without complete relief of the obstruction of the pulmonary tree, there may be recurrence of the obstruction due to the factors previously mentioned. The stage is now set for the development of atelectasis, pneumonia, and tracheobronchitis.[3] These conditions develop in a manner similar to the postoperative pulmonary complications seen in civilian life. The

same etiologic factors are involved. There is the abnormal presence of secretions and the like in the bronchial tree, and also there are similar influences preventing the expelling of this obstructing material. In the medical literature of the past decade great emphasis has been placed on the importance of the unrelieved obstruction of the bronchi as the etiologic factor in the development of these conditions in the postoperative patient. It is not necessary for us to review all of this evidence. However, we would like to particularly emphasize that in atelectasis and pneumonia following trauma to the chest, brain or abdomen there are a similar train of developmental circumstances. We have seen two cases of typical total pulmonary atelectasis admitted to the shock ward of a Forward Hospital which we believe were similar to the cases of "massive pulmonary collapse" reported in World War I. In our patients the atelectasis was clearly the result of bronchial obstruction from retained blood clots and mucus. The atelectasis cleared rapidly with the relief of the bronchial obstruction in each case. Although atelectasis and pneumonia are not uncommon following trauma, lung abscesses are extremely rare. There has been no case in our series, although several have been reported in this theater of operations.

SIGNS AND SYMPTOMS

The presence of abnormal amounts of fluid substances in the bronchial tree may be detected by certain cardinal signs and symptoms. The recognition of the syndrome in its earlier stages should lead to vigorous treatment, which will often prevent the development of graver complications. One of the most frequent findings is an almost constant "wet cough." Such a cough may even have a rattling element, which persists in spite of the fact that sputum is being raised with each effort. The wheeze or rattle continues because the sputum is being inadequately expelled, or there may be associated bronchospasm. The cough may be continuous, hacking, or more paroxysmal in character and the expulsive force is often weak. Occasionally the cough may be nonproductive in spite of strenuous efforts. When small amounts of sputum are being raised with constant repeated coughing attacks, one is tempted to infer that the drainage is adequate—a fallacious assumption. Auscultation of the lungs after coughing will reveal râles, which are evidence of incomplete tracheal drainage. This type of cough indicates that only the most superficial secretions are being raised. Thus, a cough that is continual and more or less productive is most frequently a sign of inadequate bronchial drainage.

On physical examination there are two outstanding features: dyspnea and bronchial râles. If there has been considerable thoracic trauma the dyspnea is usually due to a combination of various factors (hemothorax, mediastinal shift, *etc.*). Dyspnea may be due to painful respiration, which is of the jerky, shallow type, each inspiratory effort being limited by the pain produced. But where the thoracic damage has been minimal or in cases of abdominal or cranial injury, dyspnea frequently may mean partial bronchial obstruction with resultant anoxia. Present in practically all these cases are râles varying from high pitched wheezes (which may be evidence of associated bronchial

spasm) to medium or coarse bubbling râles. Râles may not be elicited on the examination of the patient unless auscultation is made immediately *after* coughing. Frequently sticky mucus attached to the tracheal or bronchial wall or the completely obstructed branch bronchus will not present the physical sign of râles. Fine crackles heard with the stethoscope over the patient's mouth on respiration is a sensitive index of moisture in the bronchial tree. In the early cases, the evidence of moisture heard by the stethoscope is the most important physical sign.

In the advanced cases the diagnosis is usually simple and can be frequently made at a distance by the dyspnea and audible râles. Tachycardia, cyanosis, and varying degrees of shock and even coma may be present. Psychotic manifestations due to cerebral anoxia are not uncommon. The late findings of unrelieved bronchial obstruction are those of atelectasis and pneumonia, usually associated with fever.

The character of the sputum is of diagnostic significance. Bronchial secretions assumed to arise as a result of reflex stimuli from chest trauma, irritation from aspirated material, or early infection are of a mucoid type. As infection develops in the bronchial tree, the sputum becomes more and more purulent. Hemoptysis of course usually denotes pulmonary injury. Depending on whether fresh blood or clots mixed with mucus are present, the hemorrhage is either recent or old. If thin serosanguineous fluid is raised, one must suspect an hemothorax with bronchopleural fistula. While similarly thin seropurulent sputum may point to an early empyema with bronchopleural fistula. Thin yellow, pink or colorless sputum, often mixed with air to give it a frothy appearance, is evidence of the pulmonary transudation and exudation (edema) seen in the severe cases. The sputum from the majority of patients presents a mixture of these various types.

ROENTGENOGRAPHIC FINDINGS

When the casualty arrives in the Field or Evacuation Hospitals in shock or with wet pulmonary tree, these conditions must be strenuously treated before any roentgenologic examinations are made. The frequent coexistence of extensive thoracic wall, pleural, or intrapulmonary pathology makes the shadows due to partial or complete bronchial obstruction very difficult to interpret (Case 4). In the early stages of the wet lung, roentgenographic findings are minimal and a considerable degree of obstruction may be present without roentgenographic evidence. Roentgenograms in two planes should be taken whenever possible. When any question arises more weight should be placed on the clinical picture. In certain instances, the information gained by the taking of intrapleural pressure readings, aids in the interpretation of the roentgenographic findings (Case 4). Patchy lobular atelectasis is seen early in these cases and may be indistinguishable from shadows cast by pulmonary hematoma. Later, when lobular or total pulmonary atelectasis is present, the collapse of these parts of the lung produces the classical signs of mediastinal shift and narrowing of the intercostal spaces.

TREATMENT

(A) *Prevention.*—It is important to regard every patient with a chest wound or a severe abdominal or brain injury as a potential candidate for the development of wet lung. We must keep as our objective the maintenance of an open pulmonary airway so that inspired oxygen can be made available for the alveolar capillaries. In the vast majority of instances, this may be accomplished by the prompt employment of simple preventive measures. The patient is rapidly made a fit candidate for early emergency surgery, and the undesirable sequelae previously discussed are avoided. Only those procedures that are of importance to the establishment and maintenance of an adequate bronchopulmonary air-way are considered, as the general treatment of shock is outside the limits of this communication.

On admission, all casualties with chest injury and with history of dyspnea, hemoptysis, wheezing, cough, or thoracic pain are examined carefully for signs of fluid retained in the pulmonary tree. Patients with severe abdominal or cerebral wounds must also be carefully followed from this point of view. Unless in shock or unconscious, all patients are placed in Fowler's position, in which the gravitation of abdominal contents downward allows the diaphragm to work more efficiently, both for breathing and effective coughing. When cyanosis or dyspnea is present, oxygen is administered by nasal catheter or the more efficient B.L.B. mask. If the breathing is wet the patient is encouraged to cough by manual support of the chest. It is not only the actual support of the painful chest wall that aids these patients. The patient is encouraged to cough and cannot help but be impressed with its importance when some one takes the time to come around to assist him. Small doses of morphine, judiciously employed, are of value. Doses of $\frac{1}{6}$ grain are the rule. Sometimes $\frac{1}{8}$ grain suffices, but we never used over $\frac{1}{4}$ grain. We prefer to administer the morphine intravenously as its action is more rapid and the effect can be more accurately evaluated.

Such measures as the aspiration of blood from an hemothorax or air from a pressure pneumothorax must be employed to increase the vital capacity. The dressing on "sucking wounds" should be so fixed that air is not sucked in through the chest wall opening during this period of resuscitation of the patient. Gastric distention, which may greatly immobilize the diaphragm, must be dealt with by means of the stomach tube. It is most important to correct these pathologic conditions promptly, as they contribute to the dyspnea, anoxia, and shock.

(B) *Active Measures.—1. Intercostal Nerve Block:* If the patient does not clear his bronchial tree by coughing then additional measures must be employed. Respiration is limited and cough is ineffectual if chest pain is not relieved. The abolishment of painful and other stimuli arising in the chest wall and parietal pleura may be all that is needed to effect successful clearing of the pulmonary tree. Rovenstine and Byrd,[4] and Harmon, *et al.*,[5] have reported the use of nerve block and local procaine infiltration to control chest wall pain. The technic of intercostal nerve block is simple. In brief, 5-10 cc.

of 1 or 2 per cent procaine are injected around the intercostal nerves supplying the traumatized area of the chest. To insure relief of pain, one must inject several intercostal nerves above and below those innervating the traumatized area. Pain and discomfort have been abolished for periods of time averaging not less than 24 hours (Case 1). Why the relief of pain extends beyond the pharmacologic action of procaine is difficult to explain. Relaxation of muscle spasm and improvement of the blood supply to the traumatized region may be important factors. The nerve block should be repeated as often as is necessary. If a large number of nerves need to be injected a small dose of a barbiturate should precede the injection, so that there is lessened danger of procaine reaction.

In all of our cases, with the exception of one severe case of flail chest, in which there were multiple fractures of six ribs, blocking of the intercostal nerves had made strapping of the thorax unnecessary. Tight bindings of the chest is unphysiologic, as it limits respiration and favors the retention of secretions. Frequently the patient breathes more comfortably without his chest strapped than with the strapping in place. However, in case of extreme paradoxic movement of the thoracic cage, prevention of the ballooning out of the chest wall by a firm binder may be necessary in addition to the nerve block.

Intercostal nerve block is of value not only to relieve pain but also to block stimuli that may cause reflex disturbances in the bronchi. The part played by reflex constriction of the bronchial tree and secretion of mucus, as shown experimentally by deTakats,[1] should not be overlooked. We have seen patients with chest injuries, in respiratory distress and in whom severe chest pain or shock was not the predominating factor. There was no evidence of blood in the bronchial tree, exposure to a noxious gas, infection, nor aspirated material. Wheezing, which we believe represented both bronchial spasm and mucus secretion, persisted after coughing (Case 2). Following intercostal nerve block there was cessation of wheezing and the raising of mucoid sputum. Here, the blocking of the chest wall stimuli seemed to relieve the reflex bronchial spasm and mucus secretion. It is true that usually we have a combination of the factors previously discussed, nevertheless, intercostal nerve block may be used to minimize "reflex" bronchial spasm and mucus secretion where there is chest wall and parietal pleural injury, even though pain is not prominent.

At open thoracotomy, advantage should be taken of the opportunity to block the intercostal nerves under direct vision. The nerves may be simply injected with procaine or crushed with a fine hemostat. This is an important procedure as it provides the relief of pain and diminishes the stimuli arising from the chest wall and parietal pleura during the important postoperative period. It also obviates the necessity for intercostal nerve block following surgery.

That reflex spasm of the bronchus and secretion of mucus by the bronchial glands can be initiated by thoracic injury has been shown by deTakats. Though the evidence is in nowise conclusive, certain of our clinical observations seem to substantiate the experimental findings of this worker. If this

is so, one would expect atropine to abolish these vagal impulses. However, deTakats[1] found that atropine prevented bronchospasm in only 20–42 per cent of the experimental animals, even though tremendous dosages, up to ⅙ grain, were employed. Our clinical experience with the use of atropine in these cases so far has presented conflicting evidence.

2. *Catheter Aspiration:* The measures enumerated above are continued as long as there is clinical improvement. If the patient does not improve or if there is evidence of inadequate raising of sputum, mechanical aspiration of the bronchial tree is resorted to without delay.[3] This may be performed by one of two methods—1. Catheter aspiration, as described by Haight.[6] 2. Bronchoscopy. In both, the basic aim is the removal of excess secretions in the lower air-way.

The equipment for catheter suction is almost always available and the technic is simple. With practice, anesthesia is rarely necessary so that this method can be most easily used in an emergency. The mastering of this technic by all those treating injuries of the chest, brain, and abdomen will result in the saving of many lives. Local anesthesia is indicated in certain cases with hyperirritable gag reflexes. Two per cent pontocaine or 5 per cent cocaine may be sprayed into the pharynx and painted into the hypopharynx with a curved swab or applicator. A small dose of barbiturate should be administered before the pontocaine or cocaine is used. No fluids should be ingested until the gag reflex has returned.

A source of suction delivering 15 pounds of negative pressure, a fairly stiff No. 16 or 18 urethral catheter of the Robinson type, and connecting tubing are all the materials necessary. One of us[7] has designed a portable hand suction machine which has proved of great value in the forward surgical installations, where electricity or electrical suction machines were not always available. An attachment to the windshield wiper or the gas intake manifold of motor vehicles may be used as an emergency source of suction.

The patient is placed in Fowler's position, the neck is flexed, and the tongue pulled rather sharply forward to anchor the larynx. If the patient is unconscious, the index finger of the left hand can engage the tip of the epiglottis so that the catheter is very easily passed through the larynx. In conscious patients the catheter is passed through the nostril and advanced until the larynx is reached. The catheter is then withdrawn for about one centimeter and the patient asked to take a rapid deep breath. During inspiration the catheter is quickly advanced into the trachea. Success of the maneuver will be signified by coughing, passage of air through the catheter, and hoarseness of the voice. Hoarseness of the voice is the best criterion, as we have introduced the catheter into the esophagus and noted free flow of air around the catheter in a manner simulating respiration. After the catheter has been advanced for several centimeters into the trachea, suction is begun. (Suction should not be applied until the catheter has passed the larynx). The patient is urged to cough and usually does so forcibly, due to stimulation of the tracheal mucosa. The catheter is slowly advanced and withdrawn to provoke coughing and pre-

vent excessive suction on the mucosa at any one spot. Suction is not continued for longer than five seconds at a time to allow the patient to rest. After the trachea is dry, the stem bronchi are aspirated. To enter the right stem bronchus the patient's head is turned slightly to the left. It is somewhat more difficult to enter the left stem bronchus. The patient's head must be turned far to the right and the chin somewhat elevated. The catheter should be advanced as far as possible in each stem bronchus. Frequently, the patient is rolled on his side, with the more involved lung uppermost, so that gravity will aid in draining the small bronchi. Often more sputum is coughed up around the catheter than is aspirated through the catheter. Following catheterization the patient coughs with greater efficiency because of increased ventilation. He should be watched closely however for further accumulation of secretions. Since there is no appreciable trauma to the larynx and bronchi, catheter aspiration may be repeated as often as necessary.

We have left catheters in the trachea for periods of 8-12 hours in patients in whom the rapid formation of bronchial secretions and pulmonary transudates has made aspirations every half hour necessary (Case 3). One hundred per cent oxygen was administered through the tracheal catheter constantly between aspirations. It is surprising how well these patients tolerate the catheter. Subsequent bronchoscopy in these cases showed no evidence of trauma to the vocal cords or tracheal mucosa.

In general, the catheter aspiration of the trachea and bronchi is employed in cases of wet lung whenever assisted cough is not effective. Certain specific uses of bronchoscopy will be mentioned later. All emergency tracheobronchial aspirations should be treated on the wards by the catheter method, facilities for which should be available at all times.

In the comatose patient or one practically "drowning" in his own secretions, catheter suction must be employed at once (Case 3). Delay incurred in getting the bronchoscope ready may result in irreversible changes to the nervous system caused by prolonged anoxia. In these acute emergencies catheter aspiration is frequently a life-saving measure. In postoperative cases, where the civilian experience has been extensive, catheter aspiration has proven itself of great value in the removal of aspirated material or secretions from the tracheobronchial tree.[8] Very rarely, an unusually flaccid epiglottis covers the larynx in such a way that it is impossible to pass the catheter. Catheter aspiration of the bronchial tree has as the chief advantage that it is almost instantly available, does not require the services of a skilled bronchoscopist, and may be used over and over as often as necessary.

3. *Bronchoscopy:* Although bronchoscopy is a highly specialized procedure, usually performed in the operating room, it may be accomplished by the skilled bronchoscopist without moving the patient from the bed. Thus, the fact that the patient cannot be moved does not prohibit the performance of a needed bronchoscopy. General anesthesia is contraindicated in the presence of excess amount of fluid in the pulmonary tree. Topical anesthesia must be employed. No anesthesia is necessary in some instances in semicomatose

or moribund patients. Because bronchoscopy permits direct vision of the air passages, both stem bronchi will be aspirated with more certainty, and mucus plugs blocking the orifices of the branch bronchi will not be overlooked. Curved suction tips may be inserted into the openings of branch bronchi under vision and thus effect more adequate drainage. Similarly, by the direct application of cocaine (or procaine) and epinephrine solutions to the swollen bronchial mucosa the resultant shrinkage of the mucosa further increases the air-way. Thus, bronchoscopic aspiration has the distinct advantage over catheter aspiration of being more thorough.

The decision as to whether to use bronchoscopy or catheter suction following ineffectual cough depends on the individual case. No hard or fast rule can be formulated. If mucus plugs or blood clots in the branch bronchi are expected, bronchoscopy should be performed (Case 4). Thus, bronchoscopy is preferred in proven lobar and total pulmonary atelectasis. Obstruction of the trachea or bronchi that has been present for a period of time should, if possible, be treated with bronchoscopy. If after catheter aspiration, the bronchial tree is still wet, the more thorough procedure, bronchoscopy, is usually indicated.

In cases of bronchial obstruction recurring in spite of repeated tracheobronchial aspirations, bronchoscopy is preferred. Frequently, the cause of the recurrence may be found in the fact that catheter suction has not completely removed the obstructive factor. In bilateral processes each stem bronchus is aspirated with more certainty than is possible with catheter suction. When cough is weak and ineffectual there is danger of flooding the contralateral bronchus by sudden releasing of large amounts of sputum from the obstructed bronchus. This may be obviated when the aspiration is performed under the direct vision possible with bronchoscopy. Occasionally there were patients in the forward installations where the bronchial tree remained "wet" due to retained blood or mucus. Emergency celiotomy or thoracotomy was indicated for associated wounds. Here bronchoscopy performed immediately before surgery made the anesthesia much more satisfactory (Case 3). In these cases and, in fact, in all forward thoracotomies and thoracoceliotomies we have routinely performed bronchoscopy immediately following operation. This policy gradually evolved from the difficulty we had in the postoperative management of the severely wounded patients. In the vast majority of instances this postoperative bronchoscopy kept the bronchial tree dry until the patient reacted sufficiently to raise the sputum by his own efforts.

Severely wounded patients in shock should not be exposed to the fatiguing effects of prolonged coughing. Therefore, great care must be exercised to perform the bronchoscopy as quickly as possible, watching carefully for early evidence of tiring. Oxygen, 100 per cent, should be administered through the bronchoscope during the procedure in all patients with anoxia. One must remember that often the sicker the patient, the more he may need tracheobronchial aspiration, since his precarious state may be directly the result of obstruction of the bronchial tree.

4. *Positive Pressure Oxygen:* Thus far we have discussed procedures mainly to effect the removal of fluid substances from the pulmonary tree. The escape of plasma fluid into the alveoli and branches of the bronchial tree presents a problem demanding the application of measures in addition to those already mentioned. The development of a type of pulmonary edema in the acutely injured as a result of "anoxic" anoxia, tracheobronchial obstruction, and increased respiratory effort has been presented. Excessive amounts of intravenous plasma and blood may also be important contributing factors by causing ventricular failure and pulmonary edema.

There is an increased tendency, as evidenced by the recent reports in the medical literature, to use positive pressure oxygen therapy in the treatment of pulmonary edema. The pulmonary edema seen in pneumonia;[8] gas poisoning;[9] and heart disease[10] has been successfully controlled by this method of therapy. The rationale of its use, technics of administration, and the great value of this procedure have been repeatedly shown by Barach, and his associates,[8, 11, 13] in a series of reports. Because we believed that we were dealing with a form of pulmonary edema in these injured patients, positive pressure oxygen seemed advisable. We have used a to-and-fro system containing a soda lime cannister and a rebreathing bag. Positive pressure on the bag was maintained manually, care being taken to avoid excessive pressures. First, we employed all the measures outlined to clear the fluid out of the trachea and bronchi. Edema fluid constantly forming in the alveoli and bronchioles cannot be completely removed by suction. However, the use of suction and the various measures enumerated permit the oxygen to get down to the bronchioles and alveoli. It is the administering of oxygen under positive pressure that serves to keep the bronchioles patent and opposes the hydrostatic pressure of the blood in the capillaries. The extensive work of Barach[13] has shown an increase in the vital capacity with positive pressure oxygen. Positive pressure in the respiratory system must not be raised to 10 cm. of water, as Beecher, and his associates,[12] have demonstrated deleterious effects at this level. They reported a great rise in venous pressure, fall in systolic, diastolic, and mean blood pressures as well as decreased blood flow. However, pressures from 2-6 cm. of water are considered safe by most authors on the subject.[13] In cases that had not been in shock for a long period of time, we have been successful in drying up the wet lungs due to pulmonary transudation and exudation with the use of positive pressure oxygen therapy (Case 3). While severe shock is still present, positive pressure should not be employed since it may seriously impede the return of blood to the right heart.

Some patients do not tolerate the face mask well at first. However, with sufficient encouragement the coöperation of the patient may be obtained. We believe that positive pressure oxygen should be used in these cases with definite pulmonary edema. Theoretically, it also has considerable prophylactic value. The indication for the use of positive pressure oxygen in the early stages of wet lung following trauma cannot be stated at this time. Nevertheless, from our experience, we believe it has a definite place in the treatment of these cases and that further trial of this method of therapy is indicated.

ILLUSTRATIVE CASE REPORTS

Case 1.—A 23-year-old sergeant was wounded in the chest and buttocks by an high explosive fragment in Italy, December 5, 1943. He was admitted to a Semimobile Evacuation Hospital three hours later, dyspneic, with severe chest and abdominal pain. The temperature was 98.6° F., pulse 110, respiration 30, and blood pressure 110/80. Penetrating wounds of the left chest and buttocks were present. There were signs of a large amount of fluid in the left thorax obscuring all other findings, and loud musical wheezes over the right chest anteriorly and posteriorly. A roentgenogram confirmed the presence of fluid on the left (Fig. 1). A small foreign body was seen behind the

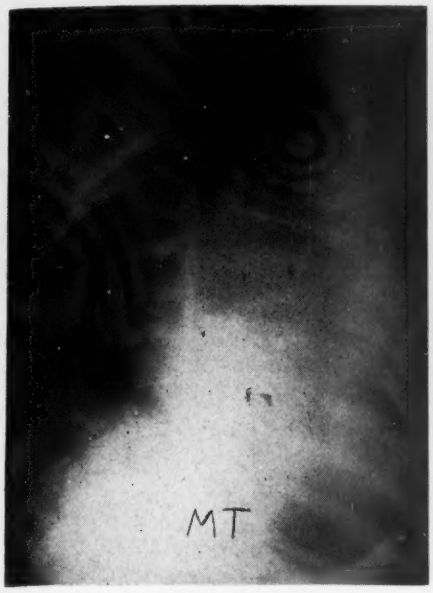

FIG. 1

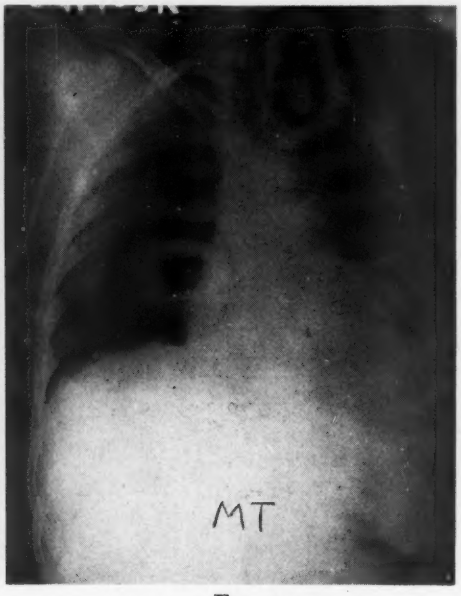

FIG. 2

FIG. 1.—Case 1: Day of injury. Fluid obscures the left chest. Left eighth rib is fractured. There is no roentgenographic evidence of the early stage of wet lung.

FIG. 2.—Case 1: Eight days after injury the lung fields are clear except for signs of residual fluid on the left.

heart and above the left diaphragm, and the left eighth rib was fractured. After ¼ gr. of morphine sulfate and 1/100 gr. of atropine sulfate intravenously the chest pain was not sufficiently relieved to permit effective coughing. The blocking of the fifth to tenth intercostal nerves on the left, resulted in the complete relief of pain. He then coughed up a large amount of old and fresh blood mixed with mucus. Following this he breathed deeply and comfortably and on auscultation the lungs sounded dry. Débridement of the chest wall and buttocks was then carried out under pentothal anesthesia. There was no recurrence of severe chest pain and he continued to raise bloody sputum for a week. A total of 2,730 cc. of bloody fluid was removed from the left chest during the first week after injury and the left lung was almost completely expanded (Fig. 2). From then on his course was entirely uneventful.

COMMENT: Retention of blood in the bronchial tree from intrapulmonary hemorrhage was, in the main, responsible for the findings of wet lung in this case. Severe chest pain unrelieved by a large dose of morphine prevented adequate cough. Blocking of the intercostal nerves relieved pain, and the patient could raise the blood and mucus accumulated in the bronchial tree.

Case 2.—A 24-year-old German prisoner of war received multiple shell fragment wounds in Italy, November 5, 1943. The wounds were dressed and ¼ gr. of morphine sulfate was given at the Clearing Station. One and one-half hours later he was admitted to a Semimobile Evacuation Hospital with dyspnea, but not in shock or severe distress. There were ten wounds of the right chest. The breath sounds were diminished over the right lung due to the presence of fluid. Over the entire left chest anteriorly there were numerous wheezes which persisted after forceful coughing. Spasm, tenderness, and rebound tenderness were noted in the right upper quadrant of the abdomen. Fluoroscopy showed a 6-mm. metallic foreign body in the right posterior inferior mediastinum and fluid in the right chest. There were several smaller foreign bodies apparently in the abdominal and thoracic wall. Exploratory celiotomy was indicated to rule out intra-abdominal injury. In spite of the fact that morphine had controlled the chest pain sufficiently to permit hard coughing, the early signs of wet lung persisted. We did not wish to proceed with the operation without attempting to dry up the bronchial tree first. Intercostal nerve block of the fourth and 12th nerves on the right side was performed. Shortly after this the wheezing disappeared and he raised mucoid sputum. The lungs now sounded dry. Exploratory celiotomy, removal of abdominal wall foreign bodies, and débridement of chest wall wounds were performed under ether-oxygen anesthesia. The patient's course from then on was uneventful and there was no recurrence of the wet lung.

COMMENT: Multiple chest and abdominal wall wounds were present without evidence of shock, pulmonary hemorrhage, or infection. The morphine sulfate alleviated the chest pain sufficiently to allow the patient to cough forcefully but early signs of wet lung persisted. Following the blocking of intercostal nerves supplying the injured part of the chest, the patient raised some mucoid sputum and the wheezes dramatically disappeared. This appears to be evidence that the intercostal nerve block resulted in a cessation of bronchial spasm and excess mucous secretion.

Case 3.—A 21-year-old sergeant received multiple wounds in Italy, January 23, 1944. He arrived in a Field Hospital three hours after injury in severe shock, with a pulse rate of 140. The blood pressure could not be obtained. A sucking wound of the left chest and penetrating wounds of the right chest, thigh, forearm, hand, and cheek were present. Signs of fluid were elicited in the left chest. The breath sounds were diminished on the right. He was in severe pain, not having had any narcotic since being wounded. After placing an occlusive dressing on the "sucking wound" ⅛ gr. of morphine sulfate was given intravenously. The dose was repeated in a short time with relief of the pain. Following the administration of two units of plasma and 500 cc. of blood, the blood pressure was 104/80, and the pulse was 132. He was raising small amounts of bloody sputum. Two hours later his condition became critical. When we were called to see him, he was comatose, cyanotic, with audible tracheal râles and a weak thready pulse. Catheter suction was performed at once and large amounts of yellow frothy sputum was aspirated. His response was dramatic. Consciousness returned. Pulse and color improved. Suction was repeated every 20 or 30 minutes, 100 per cent oxygen being administered through the catheter that was left in place in the trachea in between aspirations. The catheter was kept in the trachea for a period of eight hours, during which time his condition steadily improved. A chest roentgenogram taken at this time (Fig. 3) showed fluid in the left chest and foreign bodies in both lung fields. The catheter had slipped into the right main bronchus. Since the bronchial tree was dry, the catheter was removed. A blood transfusion of 500 cc. and one unit of plasma were given, followed by the aspiration of 100 cc. of air and 200 cc. of bloody fluid from the left chest. Two hours later (17 hours after admission) his blood pressure

was 108/74, and he was judged to be in suitable condition for surgery. One-eighth grain or morphine sulfate and 1/100 of atropine sulfate were given intravenously, as preoperative medication, prior to the administration of ether and oxygen intratracheally. Bronchoscopy was performed before surgery was started, with the aspiration of considerable amounts of bloody sputum from both main bronchi. No evidence of trauma to the larynx or tracheal mucosa from the tracheal catheter was seen. The sucking wound of the left chest was débrided. The internal mammary vessels were found to be lacerated. Although not bleeding, they were ligated. A laceration of the upper lobe of the left lung was sutured with fine silk. Several small metallic foreign bodies present in the pericardium

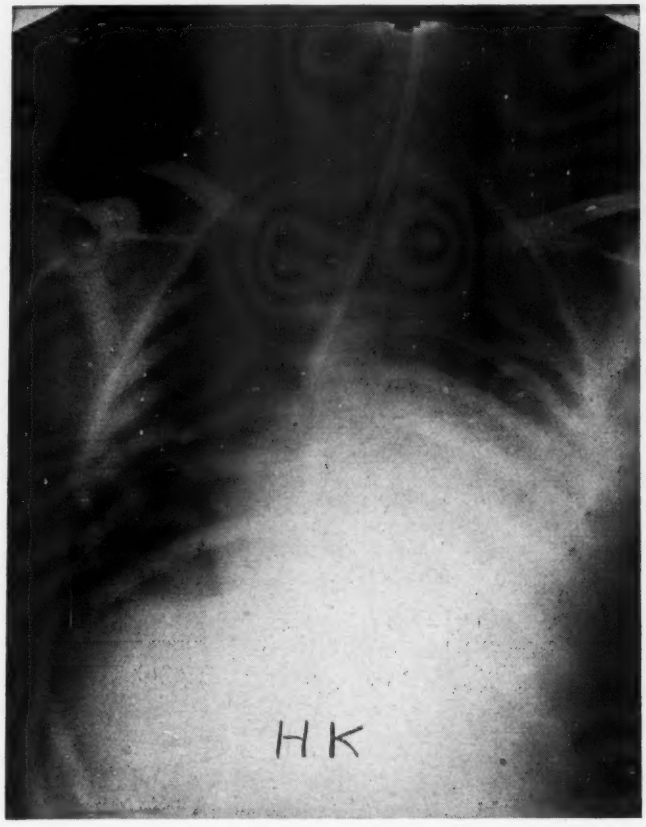

FIG. 3.—Case 3: Day of injury. Fluid obscures lower three-fifths of the left chest. Foreign bodies and some mottling of the right lung field are present. Catheter is seen in upper portion of the right stem bronchus.

were removed. An attempt to remove the foreign body in the lower lobe of the lung was not deemed advisable. The chest wall was closed in layers leaving the skin open. An intercostal drainage tube was used. A foreign body was removed from the right chest wall, but no attempt was made to remove the foreign body in the right lung. During the performance of the thoracic surgery another surgical team débrided the other wounds. One unit of plasma and 500 cc. of blood were administered during the operation. Postoperative bronchoscopy was performed with the aspiration of a moderate amount of bloody mucus from both stem bronchi. His immediate postoperative condition was satisfactory.

On the day after operation he became disoriented, which condition we attributed to

cerebral anoxia, in spite of the fact that oxygen was administered by nasal catheter. Although his cough was productive of thin yellow fluid, the pulmonary tree seemed to be filling up with moisture, and his condition rapidly became critical.

The temperature was 99.4° F., the pulse was 150, and the respirations were 48 per minute. Following tracheobronchial catheter aspiration his breathing was less noisy and the tracheal bronchi and coarse bronchial râles disappeared. However, medium and fine râles could be heard with the stethoscope diffusely over all lobes of the lungs. It appeared that fluid was being formed in the peripheral portions of the lungs more rapidly than it could be removed. The clinical picture was similar to that seen in pulmonary edema accompanying heart disease, gas poisoning, and other conditions. Because we were

FIG. 4

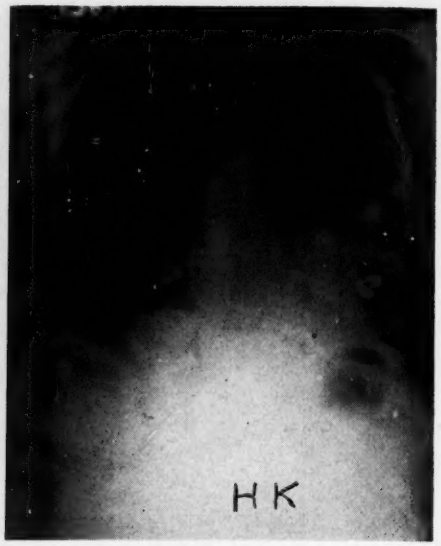

FIG. 5

FIG. 4.—Case 3: Second day after injury. There is mottling of both lung fields and marked subcutaneous emphysema is present.

FIG. 5.—Case 3: Fourteen days after injury. There is some residual mottling of the left lung. Subcutaneous emphysema persists.

convinced that we were dealing with true pulmonary edema positive pressure oxygen (not exceeding 6 cm. of water) was administered with a to-and-fro system containing a soda lime cannister. After about 15 minutes time there was a definite improvement in the patient with a disappearance of the cyanosis. The râles now disappeared except for a few fine râles at the bases and the pulse rate fell to 120. The respirations were less labored and decreased to 32 per minute. After 15 minutes more the positive pressure oxygen was stopped and oxygen was administered by the B. L. B. mask. During the next 24 hours he had two additional attacks of pulmonary edema resembling the one cited. In both of these instances the administration of oxygen under mild positive pressure resulted in a "drying up" of the lungs, a decrease in pulse and respirations, and a dramatic improvement in the patient's condition in a similar manner.

COMMENT: This case is of the utmost interest as an example of the therapeutic problem presented by wet lung occurring in a patient with multiple chest and other wounds. After his arrival at the field hospital tracheobronchial catheter aspiration was performed and oxygen administered for eight hours intratracheally in addition to the cautious fluid replacement therapy. Through the continued use of these technic the patient was brought out of

shock and made a suitable candidate for closure of his sucking wound and débridement of the other wounds. Bronchoscopy performed just before and after operation aided in the maintenance of an air-way during operation and helped his immediate postoperative courses. Later, on three occasions what appeared to be true pulmonary edema developed. The administration of oxygen under mild positive pressure in each instance resulted in "drying up" of the lungs, decrease in pulse and respiration, disappearance of the cyanosis, and marked general improvement. The exact pathologic physiology responsible for the development of pulmonary edema in this case is not completely understood. Anoxia due to severe trauma to both lungs and tracheal obstruction for mucus and blood were probable important factors. We do feel certain, however, that it was the continued use of the procedures mentioned above that was responsible for the successful outcome of this case.

Case 4.—A 27-year-old lieutenant sustained a "sucking" chest wound, July 19, 1943. This wound was treated by an occlusive dressing and within 24 hours a primary pleural closure was done, leaving the skin unsutured. He expectorated small amounts of pure blood for three days. The patient was admitted to the thoracic surgery center five days after injury. He was moderately dyspneic on exertion, comfortable at rest. He had a wet cough, productive of only small amounts of blood-tinged, mucoid sputum. There were a few coarse râles parasternally on the right. Roentgenograms on the day after admission showed a right-sided hydropneumothorax without cardiac shift (Fig. 6). There were comminuted fractures of the fifth and sixth ribs posteriorly. On the day after admission and the following day, 360 cc. and 390 cc. of old pleural blood and air, respectively, were removed from the right chest. Following each aspiration, highly negative intrapleural pressure prevented the continuance of the procedure. The wet cough continued and did not improve in spite of the administration of CO_2 and frequent changes in position. Roentgenograms on the following day showed a minimal residual hemopneumothorax, expanded upper lobe and atelectasis of the right middle and lower lobes (Fig. 7). Bronchoscopy was, therefore, indicated. Bronchoscopic aspiration was productive of large amounts of blood clots and mucus, which had partially formed bronchial and bronchiolar casts. The patient's cough became loose, remained productive for four days following aspiration, then ceased altogether. Roentgenograms taken 18 hours following bronchoscopy showed almost complete reaeration of the right middle and lower lobes (Fig 8). In eight days, the right lung had completely expanded and was rapidly approaching normal (Fig. 9).

COMMENT: The roentgenographic evidence of atelectasis was obscured by the hemothorax. The following points in the history should, however, make the diagnosis almost certain without roentgenographic proof: Continued wet cough with inadequate expectoration; extensive hemopneumothorax without cardiac shift; and the development of severe negative pressure symptoms following aspiration of relatively small amounts of fluid. The aspiration of old blood clots and mucus by bronchoscopy resulted in the prompt reëstablishment of the air-way and reëxpansion of the lung. Earlier attention to the patient's wet lung according to methods outlined in this communication, might have obviated the occurrence of this complication; atelectasis.

DISCUSSION: In presenting the clinical problem of wet lung following trauma we have discussed under this term everything from the beginning moisture in the pulmonary tree to the full-blown pulmonary edema. Atelecta-

FIG. 6

FIG. 7

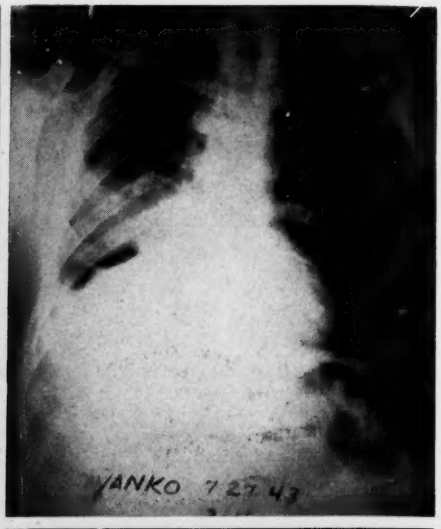

FIG. 8

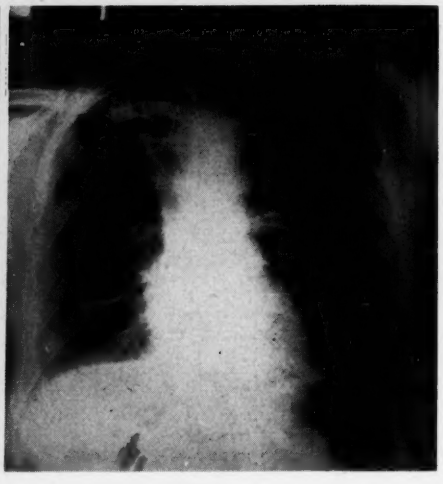

FIG. 9

FIG. 6.—Case 4: Admission roentgenogram, five days after injury. Right hydropneumothorax, without cardiac shift, is present.

FIG. 7.—Case 4: Day after admission. Seven hundred fifty cubic centimeters of blood and air have been removed from the right chest. Although the upper lobe is expanded, there is persistent atelectasis of the right middle and lower lobe.

FIG. 8.—Case 4: Immediately following bronchoscopy. The middle and lower lobes are expanding.

FIG. 9.—Case 4: Four days after bronchoscopy. The right lung is expanded.

sis and pneumonia are emphasized as the important sequelae. Some will argue that this term might better be reserved for only the fully developed picture of pulmonary edema seen in the acutely injured. We have purposely included the milder states for we wish to emphasize the importance of relatively small amounts of fluid in producing obstruction to the pulmonary air-way. The retention of fluid substances in the bronchial tree may initiate a set of circumstances that greatly alter the pulmonary physiology. Unless this train of events is broken up by the measures we have discussed, serious complications set in. On the other hand, once the patient is successful in keeping his pulmonary tree free of fluid material, he is usually well on the way to recovery.

We are impressed more and more as time goes on with the important rôle that anoxia plays in increasing the degree of shock in acutely injured patients. The therapeutic measures advocated, in the main, are those which improve the respiratory air-way and provide adequate oxygen supply to the pulmonary capillaries, even though it means "forcing" the oxygen into the alveoli under mild positive pressure. In our experience in the Forward Hospitals, edema of the lungs appeared to be the most significant finding at autopsy in patients who survived the initial shock but later died of their chest injury.

There may well be other mechanisms to disturb the pulmonary physiology in these cases in addition to the ones presented. Neither time nor the facilities have been present for an adequate study of this problem in the forward surgical installations.

Elaborate investigation of the cardiopulmonary functions of these patients would be desirable, supplemented with experimentation on laboratory animals. Although the pathology is not completely understood, we do know from our study of this large series of traumatic cases that this clinical state presents one of the most serious problems confronting the surgeon in the forward installations.

CONCLUSIONS

1. The problem of the wet lung following trauma has been presented.

2. In the severely wounded, there are many factors which favor the accumulation and persistence of fluid in the pulmonary tree.

3. The altered physiology resulting from the retention of fluid in the respiratory tract is discussed.

4. In restoring the normal physiology, the therapeutic measures that are most important are intercostal nerve block, tracheobronchial aspiration either with the catheter or the bronchoscope, and positive pressure oxygen therapy.

5. Illustrative case reports are presented.

6. The treatment of wet lung is one of the most challenging problems facing the surgeon handling the severely wounded.

REFERENCES

[1] DeTakats, Geza, Fenn, S. K., and Jenkenson, E. L.: Reflex Pulmonary Atelectasis. J. A. M. A., **120**, 686, October 31, 1942.

DeTakats, Geza, Beck, W. C., and Fenn, S. K.: Pulmonary Embolism Surgery, **6**, 330, September, 1939.

[2] Drinker, Cecil K., and Warren, Madeleine F.: The Genesis and Resolution of Pulmonary Transudates and Exudates. J. A. M. A., **122**, 269, May 29, 1943.

[3] Dolley, Frank S., and Brewer, Lyman A., III: Chest Injuries. ANNALS OF SURGERY, **116**, 668, November, 1942.

[4] Rovenstine, E. A., and Byrd, M. L.: The Use of Regional Nerve Block During the Treatment for Fractured Ribs. Am. J. Surg., **46**, 303, 1939.

[5] Harmon, P. H., Baker, D. R., and Kormegay, R. D.: Uncomplicated Fractures of Ribs and Major Injuries of the Chest Wall: Treatment by Infiltration with Local Anesthetic. J. A. M. A., Surg., **118**, 30, January 3, 1942.

[6] Haight, Cameron: Intratracheal Suction in the Management of Postoperative Pulmonary Complications. ANNALS OF SURGERY, **107**, 218, February, 1938.

[7] Brewer, Lyman A., III: Portable Hand-driven Suction Machine. The Bulletin of the U. S. Army Medical Department. No. **75**, 119, April, 1944.

[8] Barach, Alvan L.: Physiologically Directed Therapy in Pneumonia. Ann. Int. Med., **17**, 812, November, 1942.

[9] Segal, Maurice S., and Aisner, Mark: The Management of Certain Aspects of Gas Poisoning: With Particular Reference to Shock and Pulmonary Complications. Ann. Int. Med., **20**, 219, 1944.

[10] Pulton, E. P.: Left-sided Heart Failure with Pulmonary Edema: Its Treatment with "The Pulmonary Plus Pressure Machine." Lancet, **2**, 981, 1936. (Quoted by ref. 11.)

[11] Barach, Alvan L., and Molomut, Normal: Oxygen Mask Metered for Positive Pressure. Ann. Int. Med., **17**, 820, November, 1942.

[12] Beecher, Henry K., Bennett, H. Stanley, and Bassett, David L.: Circulatory Effects of Increased Pressure in the Air-way. Anesthesiology, **612**, November, 1943.

[13] Barach, A. L., Martin, J., and Eckman, M.: Positive Pressure Respiration: Its Application to the Treatment of Acute Pulmonary Edema. Ann. Int. Med., **12**, 754, December, 1938.

PENETRATING WOUNDS OF THE CHEST

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A TOTAL of 402 patients with penetrating or perforating wounds of the chest were treated in a General Hospital during the campaign in Italy from November, 1943, to September, 1944, and in Eastern France from November, 1944, to February, 1945. It is the purpose of this paper to discuss the problems encountered, together with such conclusions as can be drawn from our observations. During the same period of time an equally large number of patients with chest wall injuries, pulmonary contusions and blast injuries of the lung had been treated. Many of these have had associated hemothorax, but have not been included in this study because the wounds had not penetrated the pleural cavity.

Final end-results cannot be discussed at this time for several reasons. The expression "returned to duty" cannot be accepted as an end-result until it can be shown that such patient remained at full duty, or even limited duty. It has been our experience as well as that of others that some patients have been returned to their outfits designated as fit for duty and have been returned after short periods of time to other hospitals for reclassification on the basis of pain, dyspnea, *etc.* A complete follow-up study will be responsible only after the war, and may well reveal flaws in our conception of the fate of the posttraumatic chest.

Our patients were received for the most part from Evacuation or Field Hospitals. A few were admitted directly following accidents occurring in the vicinity; and another group was admitted from the Front without preliminary treatment in Forward Hospitals. This occurred during the early days of the Anzio and Southern France invasions.

We were thus able to follow with considerable interest the transition in Forward chest surgery with its increasing emphasis on conservatism. Certainly, patients are being received at present with pulmonary injuries and retained foreign bodies who would have been treated by formal thoracotomy at Forward installations a year ago. It is our feeling that this conservatism is more than adequately justified by results. We have been favorably impressed by the condition on arrival of patients who have had no more elaborate treatment than débridement and aspiration, or débridement and closure of sucking wounds. As will be shown later, many of these patients require no further formal intrapleural surgical treatment.

It is perhaps in order to discuss the most favorable location of hospitals for definitive chest surgery. We feel that this is best carried out at the nearest hospital, where an uninterrupted convalescence can be expected. If military conditions would permit patients to be held for 30 to 60 days at the Evacuation or Field Hospitals, these would be ideal locations for all definitive surgery. As this is obviously impossible the next best solution is the Forward General Hospital, with the least possible delay *en route.* The importance of minimal

delay in travel will be shown in detail in the discussion of thoracentesis and blood transfusion. This point of view was brought forward by Nicholson and Scadding,[1] and further by Churchill[2] in his presentation of the surgical problems encountered during the Italian campaign.

HEMOTHORAX

Hemothorax is by far the commonest single complication of penetrating wounds of the chest, occurring 326 times in our series of 402 cases. These represent 78.5 per cent of the total number of cases studied. One hundred and twenty of these hemothoraces were complicated by pneumothorax.

Hemothorax usually occurs immediately as a result of wounding, but the delayed appearance of hemothorax has been observed by the authors and will be discussed below. Bleeding is usually from a lacerated lung or intercostal vessels. We have never seen bleeding from large pulmonary or mediastinal vessels since they rarely arrive alive even at Field or Evacuation Hospitals.

We have not aspirated small, asymptomatic hemothoraces, and have found that almost all of these will disappear in a short time if early ambulatory activity is encouraged. If a hemothorax is small and complicated by fever, dyspnea or pain in the chest, aspiration is carried out for both diagnostic and therapeutic reasons. Many times pain can be relieved by the removal of a small amount of blood.

The large hemothorax must be aspirated early and frequently in order to obtain satisfactory results. The prime purpose of aspiration is to obliterate abnormal pleural space and allow the lung to reëxpand. This is essential if the pulmonary dynamics are to be restored to normal.

The Baxter transfusion vacuum bottle and valve are used for aspiration (Fig. 1). We have found the use of this apparatus to be a simple, air-tight and sterile method for the removal of chest fluid. It allows the removal of 600 cc. of blood or air at one time, and the rate of removal can be easily adjusted by the use of the valve. The interspace of choice for thoracentesis is determined by roentgenographic and physical signs, and is usually at the lowest level of the fluid. Percussion note is the most reliable single sign according to our experience. Absence of breath sounds may be the result of splinting of the chest and decreased respiratory excursion and cannot always be interpreted as an indication of fluid. It has also been noted in several of our cases that breath sounds may be heard through an empyema or hemothorax. D'Abreu[3] mentions this phenomenon.

The removal of 600 cc. at one time has been practiced and we have rarely exceeded this amount. Aspiration of larger quantities result in untoward symptoms such as cough, pain in the chest and feeling of faintness. When these symptoms appeared aspiration was discontinued immediately. We have preferred to remove 600 cc. amounts frequently rather than larger amounts at one time in order to avoid these alarming symptoms.

The injection of air into the pleural space following thoracentesis was not used in any of our cases. We do not share the opinion that air replacement

will prevent further bleeding from the expanded lung. That bleeding recurs after aspiration is conjecture and is not validated by proof. We have found the opposite to be true by studying the hematocrit, hemoglobin and plasma protein of hemothorax fluid. A sample of the aspirated fluid was studied by the Van Slyke copper sulfate method after each aspiration and it was found that in no instance was there evidence of increased bleeding. In fact, in all patients, aspirated more than once, there was a definite progressive decrease

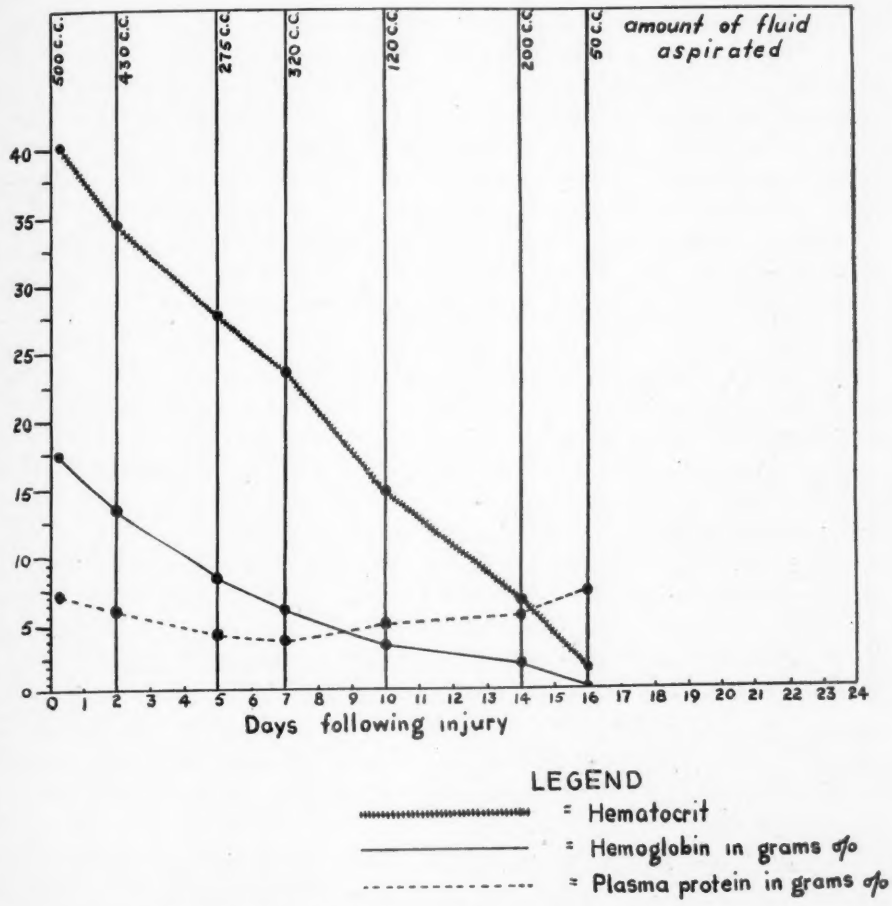

CHART I.—Showing changes in hemothorax fluid in a patient aspirated a few hours after receiving a penetrating chest wound.

in the hematocrit and hemoglobin readings of the fluid. The plasma protein usually showed a terminal rise and this fact coupled with the fact that the hematocrit and hemoglobin decreased steadily is presented as evidence that increase in hemothorax fluid is due to exudation and not recurrence of bleeding. Exudation may be the result of pleuritis. Chart I shows the changes in hemothorax fluid in a patient received a few hours after injury and is typical of the curves obtained in the other cases studied.

It has been stated that obliteration of abnormal pleural space is one of the primary purposes of aspiration and it is logical that air replacement defeats this purpose. Air injected into the pleural space tends to rise, thereby compressing the apex of the lung. If empyema is inevitable it will be total if the apex is collapsed; and the difficulty of healing a total empyema is well appreciated.

The delayed appearance of hemothorax was noted in several instances, and was usually in patients with small, perforating, bullet wounds of the chest. These patients were evacuated from Forward installations with apparently dry pleural spaces and shortly after arrival at this hospital the presence of hemothorax was evident. This might be explained on the basis of late liquefaction of pleural blood clots with subsequent exudation. Clot liquefaction may open previously sealed bronchopleural fistulae and result in tension pneumothorax. Four patients arrived at this hospital with severe tension pneumothorax which had its onset in transit. Many more patients arrived, complaining of dyspnea and pain which were not present before evacuation to this hospital. These patients stated that they were comfortable before they were transported and that their alarming symptoms appeared during transportation.

Elevation of temperature in patients with hemothorax presented an interesting problem. Eighty-seven patients showed a daily temperature rise of over 100° F. for more than five days and some for as long as three weeks. None of these patients developed empyema, nor did smear and culture studies of their hemothorax fluid show bacterial contamination. Their fever could not be attributed to concomitant wounds. We found that daily aspiration, with subsequent disappearance of hemothorax, almost always brought about a decrease in the temperature to normal.

Clotted hemothorax has been the subject of much controversy among thoracic surgeons in World War II. A distinction must be made between an inaspirable hemothorax and a clotted hemothorax. The clotted hemothorax obviously is not aspirable, but it does not necessarily follow that the inaspirable hemothorax is clotted. The traumatized chest wall and lung are prone to form many bands and points of adherence which may make aspiration difficult or even impossible.

It has been our practice to treat uninfected inaspirable hemothorax conservatively, by repeated attempts at aspiration, blood replacement, early ambulatory activity and breathing exercises. If at the end of five weeks there was no evidence of expansion of the lung and disappearance of the blood, a thoracotomy and decortication were done. There were 41 cases considered inaspirable and of these only 11 required decortication after five weeks of conservative therapy. The remaining 30 patients showed adequate reëxpansion and disappearance of fluid at the end of this five-week period and no surgical treatment was necessary. Five patients with total empyema were decorticated.

The above observations and facts have convinced us that hemothorax, the commonest complication of penetrating chest wounds, is best treated early

and diligently. In order to carry out these aims, these patients should be retained in General Hospitals close to Field and Evacuation Hospitals, and not passed through a long chain of evacuation to Base sections.

FOREIGN BODIES

Seventy patients with intrathoracic foreign bodies were received. These were removed in 25 instances. In 19, operation was performed primarily for the removal of foreign bodies and in the remainder removal was incidental to other procedures. The rôle of the retained foreign body in the causation of intrapulmonary or intrapleural suppuration has never been thoroughly settled. Academically, it would seem that retained foreign bodies predispose to infection, and it is perhaps fair to say that they do act as a *locus minoris resistentiae*. We do know, however, that a large proportion of these remain asymptomatic for the life time of the individual. It is equally true that a small proportion of them result in early suppuration, and a still smaller proportion is responsible for hemoptysis or suppuration in later years. There are no statistics available to indicate the frequency of these as late complications and a careful post-war follow-up could be very useful in establishing a working rule for the therapy of retained foreign bodies. It is our impression that in the absence of complications the present trend is toward conservatism.

We feel that the size and surface area, together with concomitant presence of cloth, débris, *etc.*, are the most important factors in the production of infection. This presupposes that all foreign bodies are unsterile. It has been stated that the irregular foreign body is a more frequent offender than the smooth one, which may be true. Certainly, the irregular fragment has a much greater surface area upon which contaminants may be carried. It has been further stated that bone fragments are likely to be more harmful than metallic fragments, but this has not been our experience.

In the absence of known suppuration it is our policy to remove all large foreign bodies (2 cm. and over); those projecting into the pleural cavity or diaphragm; those within or adjacent to the pericardium, and all others which appeared to be the cause of persistent symptoms of cough or pain. We have not encountered large mediastinal foreign bodies but agree that their removal is indicated when feasible.

It has also been our custom to remove such foreign bodies as are easily available during the performance of other intrathoracic procedures. Obviously, all foreign bodies known to be the source of sepsis should be removed.

Total cases with intrathoracic foreign bodies:

Foreign bodies—total cases	70
Removal in this hospital	25
Removal as primary procedure	19
Removal incidental to other procedures	6

In one case a pulmonary abscess, demonstrable roentgenographically, had formed about a foreign body. In four cases minute abscesses otherwise unsuspected have been found about foreign bodies during removal. It was not

uncommon to find cloth and débris with the foreign body without evidence of suppuration. There was no incidence of empyema except for one small basal empyema which followed decortication for total putrid empyema with retained intrapleural foreign body. A giant lung abscess which formed about a large foreign body with adherent clothing was drained in one stage without difficulty or complication.

Location of intrathoracic foreign bodies:

Intrapulmonary	15
Intrapleural	8
Intradiaphragmatic	2

ABDOMINOTHORACIC INJURIES

There were 96 cases of abdominothoracic injury, 89 of which had been operated upon at Forward installations. Seven received their initial surgery in this hospital. Three of this latter group demonstrate the ease in which this complication may be overlooked. In these three the existence of the thoracic injury had been recognized, but for one reason or another the more serious complication had been overlooked. Clinical study of the probable track of the missile, together with roentgenography, should make the diagnosis possible in the absence of more obvious signs. In one of our cases, with an entrance wound in the right scapula and an exit wound in the right groin, previous examiners had considered both wounds to be individual entrance wounds. In another instance the thoracic wound was appreciated, but the presence of a large missile in the pelvis was overlooked. Fortunately, no serious complications resulted from the delayed (48–72-hour) operative treatment.

In 23 cases, 22 left-sided, the operative approach was transdiaphragmatic through a thoracotomy incision. This was highly satisfactory, though in two cases formal celiotomy was added for further exploration. Colostomy, of course, required an abdominal incision. Wounds of the right side were usually treated by thoracotomy and celiotomy.

The operative procedures were as follows:

Thoracoceliotomy	23
(In addition there were 2 supplemental celiotomies)	
Thoracotomy	38
Thoracotomy and celiotomy	14
Celiotomy (alone)	11
Celiotomy plus débridement of chest wall	8
Débridement	8
No treatment	2

We have previously discussed the advantage of the transdiaphragmatic thoracoceliotomy.[4] As our experience has increased, we have become further convinced that this approach is ideal for splenectomy. Nephrectomy, when indicated, may be performed with ease through the diaphragm, as well as suture of lacerations or perforations of the stomach.

The incidence of injury to intra-abdominal organs is shown in the accompanying table. Frequently two or more organs were injured by the same missile. The diaphragm alone was injured in 12 instances.

Liver	52
Spleen	15
Kidney	12
Stomach	12
Small intestine	8
Large intestine	7
Pancreas	3

Complications of thoracoceliotomy were fewer than might be expected. No evidence of postoperative diaphragmatic hernia was noted, though its possible occurrence as a late complication cannot be disregarded. Complications of abdominothoracic injuries were as follows:

Empyema	5
Empyema and lung abscess	1
Liver abscess	1
Liver and lung abscess ("collar-button" type)	1
Osteomyelitis of rib ends	2
Intestinal obstruction	1

There was one fatality due to gradual failure of kidney function. This case will be discussed later.

CONTUSION

Simple contusion of the lung with no demonstrable hemothorax was present in 45 patients, or 11.25 per cent; of these, nine developed pneumonia, with clinical and roentgenographic signs. They cleared rather rapidly under sulfadiazine and supportive therapy. Simple contusion usually cleared within 10–20 days following injury. Hemoptysis occurred occasionally, but was never copious or of long duration in our cases.

LUNG ABSCESS

Lung abscess occurred three times in the 402 cases, once around a large retained shell fragment and once in a patient with a large empyema and pneumonia of the underlying lung. The third lung abscess involved most of the lower right lobe and communicated with a liver abscess through a diaphragmatic fistula. These patients all recovered following surgical drainage. Lung abscess has been discussed elsewhere by the authors.[5]

WOUNDS OF THE PERICARDIUM AND HEART

A total of 12 pericardial or cardiac wounds were encountered. Three patients had fragments removed from the ventricular musculature, one had a fragment removed from the pericardial space between the pulmonary artery and aorta. These procedures were done at Forward Hospitals. The remaining eight patients had penetrating or lacerating wounds of the pericardium with pericardial effusion varying from slight to severe. Three patients were

evacuated with small foreign bodies retained within the pericardial sac. One of these still had signs of pericarditis and was febrile. This patient was the only one of the group of 12 who had any febrile reaction or evidence of pericarditis when evacuated. One patient with tamponade could not be aspirated by the conventional method. The sixth left costal cartilage was resected through a precordial incision, and the pericardial sac was drained and 5,000 units of penicillin instilled into the pericardial cavity; recovery was good. Our conservative therapy of pericarditis with effusion consisted of oxygen, when indicated, and full doses of penicillin and sulfadiazine. Both of these drugs were used because of the uncertainty of the type of infecting organism, if any. There were no deaths.

EMPYEMA

In the 402 cases discussed, empyema was encountered 34 times, or 8.4 per cent of the total. Seventeen of these patients had thoracotomies done at Forward Hospitals, two had thoracotomies done at this hospital, 15 developed empyema without a preceding thoracotomy. Ten of the 34 patients had established empyema on admission to the hospital. Eight of these ten had had formal thoracotomies at Forward Hospitals. The above figures tend to indicate that empyema is slightly more common following early formal intrapleural surgery. This difference may be dismissed by the fact that patients requiring thoracotomy Forward usually had more severe chest wounds.

Empyema, if small and basal, offers no great problem in treatment, and if drained early and adequately almost always heals. The distressing problem is the total empyema with apical collapse. This is the type that requires decortication and may result in chronic empyema. Decortication for total empyema was necessary in only five of our cases. The remainder were treated by rib resection. We have favored the use of the Leahy tube (Fig. 2) for empyema drainage. It affords a means for maintaining adequate placement of the tube flush to the chest wall and also allows irrigation of the empyema cavity without disconnecting the under-water drainage which we have used almost routinely. The muscle and skin can be closed in layers with interrupted silk around this tube to guarantee an air- and water-tight drainage system. We believe that water-sealed closed drainage with a large tube (Fig. 3) brings about a more rapid obliteration of the empyema cavity. The negative pressure exerted is favorable for expansion of the underlying lung.

If empyema is inevitable it is best to strive for a small localized one, and early and frequent aspiration of the hemothorax or hydrothorax is strongly recommended to attain this result. Everything must be done to bring about early and rapid expansion of the lung and the following points are emphasized: diligent maintenance of normal blood level; early ambulatory activity and early and frequent aspiration.

PNEUMONIA

Pneumonia has been a troublesome but not severe complication in patients with penetrating chest wounds. It was recognized by the usual roentgeno-

graphic and clinical signs of consolidation. The diagnosis of pneumonia was made in 38 of our cases and, interestingly enough, 20 of these had their consolidation in the uninjured lung. This may be explained by the fact that generalized thoracic splinting occurs following chest injury and that patients tend to lie on their uninjured side, thereby decreasing the pulmonary excursion. The hypotasis and relative pulmonary inactivity predisposes to atelectasis and pneumonia. Twelve of these patients developed pneumonia while receiving penicillin. Full doses of sulfadiazine were used in preference to penicillin. One patient developed a small empyema; and one had a small pleural effusion which cleared rapidly after aspiration. One developed a lung abscess and is discussed under that subject. There were no deaths due to pneumonia.

GENERAL CARE

In the general care of these patients emphasis is placed upon blood replacement, nutrition, and prevention and control of invasive infection. It is logical to assume that a patient with a large hemothorax has lost a large amount of blood and suffers from anemia just as severely as a patient who has lost 1,000 cc. of blood externally. It is, therefore, extremely important to correct the anemia due to hemothorax with adequate whole blood transfusions. For example, in one patient, who was received one hour following a perforating gunshot wound of the chest, the copper sulfate studies of the aspirated chest fluid revealed an hematocrit of 48; hemoglobin of 16.8 Gm.; and plasma protein, 6.8 Gm. The venous blood taken at the same time revealed an hematocrit of 28; hemoglobin of 9.2 Gm.; and plasma protein, 6.5 Gm. Six hundred cubic centimeters of blood were removed at preoperative aspiration and 800 cc. were removed at the time of débridement and closure of the sucking wound. This patient was aspirated at daily intervals following the initial surgery, and between 200 and 500 cc. of blood were removed daily for four days. It is obvious that this patient required multiple transfusions in order to maintain normal blood volume and content. In order to make a patient ambulatory at an early date the blood must be maintained at a normal level.

Early ambulatory activity is essential and valuable because it promotes general muscular exercise and increased respiratory excursion. In order to bring about complete expansion of a totally or partially collapsed lung, a complete respiratory excursion is important. Deep breathing is most easily achieved by ambulation.

Anemia due to blood loss in this series of cases was rather marked, as shown by the following figures. Many of these patients had associated extremity wounds which contributed to the degree of anemia noted. The Van Slyke copper sulfate method for determination of hematocrit, hemoglobin and plasma protein was used. Patients with an hematocrit of 40, or over, were not considered to be suffering from anemia of blood loss. An hematocrit of 36 to 40 was considered evidence of slight anemia; an hematocrit of 31 to 36, moderate anemia; and an hematocrit below 30, severe anemia. The percentages in the various groups are listed:

Hematocrit	Percentage	Grade
Over 40	17.2	No anemia
36–40	41.6	Slight anemia
31–36	24.6	Moderate anemia
26–30	12.2	
21–26	3.9	Severe anemia
15–20	0.5	

These figures show that 82.8 per cent of the patients admitted had anemia of some degree which required transfusion. In the group classified as slight anemia, 500 to 1,000 cc. of whole blood were usually sufficient to restore the level to normal and maintain this level unless there was complicating sepsis or increasing hemothorax. In the more anemic group, transfusions of 1,000 cc. of whole blood repeated as often as necessary were given. We have been impressed by the clinical improvement in patients when the hematocrit was maintained at the normal level.

The rôle of whole blood in combating infection is well-accepted and should not be neglected. Even when hemothorax fluid shows a marked decrease in hematocrit and hemoglobin, the plasma protein content is usually sufficient to indicate a rather marked loss of protein from the body tissues or blood stream. We believe that this fact has been overlooked, and have emphasized the necessity of high protein diet and plasma transfusions in order to overcome this protein loss. For example, a patient with a chest wound of three weeks duration was aspirated, and 600 cc. of amber fluid was removed from the right pleural space. The hematocrit was 0, hemoglobin 0, and plasma protein 8.8 Gm. This corresponds to the loss of 52.8 Gm. of protein and must, of necessity, be replaced if adequate healing is to be expected. If the patient's general condition and appetite permits, the most desirable way to provide this protein is through his diet. If this is not possible plasma or whole blood transfusions should be used. The rôle of vitamins in wound healing and general nutrition needs no discussion, and may be dismissed by saying that all these patients received an adequate daily dose of polyvitamins.

Penicillin in doses of 25,000 units intramuscularly, every three hours, was given to all patients on admission and continued until there was no evidence of infection or until no effect was obtained clinically. The continued administration of penicillin was necessary only in a small number of cases. It was interesting to note that routine administration of penicillin did not prevent the complication of atelectasis and pneumonia in patients confined to bed. Twelve patients developed clinical and roentgenographic evidence of pneumonia in the injured or uninjured side while receiving penicillin. In these cases sulfadiazine was given along with penicillin and the pneumonia subsided rather rapidly. Patients with injuries of the chest wall and lung tend to lie on their uninjured side for reasons of comfort. This was discouraged and the patients were kept in a sitting position or on their injured side with adequate padding. When the uninjured side of the chest is dependent there is partial splinting of the chest wall, which prevents complete respiratory excursion, increases the anoxia and may result in atelectasis and pneumonia.

The importance of maintaining mobility of the injured side of the chest was carefully explained to the patients, and they were instructed in deep breathing exercises with emphasis on conscious use of the intercostal muscles and the diaphragm. We believe that this prevents many of the fused chests and deformities which were formerly seen in severe chest wounds. Oxygen was used when cyanosis was evident. Usually the nasal catheter was used

FIG. 1.—Apparatus used for aspiration of chest fluid. The needles, syringe and valve with tubing and adapter are prepared in small sterile packages, making bedside thoracentesis extremely simple and practical.

FIG. 2.—Leahy tube for empyema drainage. The irrigating catheter is incorporated into the lumen of the drainage tube. The rubber flanges are approximated with an hemostat and then released after the tube is placed into the empyema cavity. The tube is easily removed by a moderate pull.

to administer the oxygen. We have not found the use of respiratory stimulants indicated or necessary in these cases. Early physiotherapy to the chest wall and to the shoulder girdle are extremely important in restoring normal pulmonary function. This was carried out after all soft-tissue wounds were healed. Ambulatory activity and physiotherapy were tolerated early; and we believe that these, coupled with repeated aspiration of hemothorax and the use

of penicillin have been instrumental in maintaining a low percentage of complications.

CONTROL OF PAIN

Every effort should be made to avoid the use of respiratory-depressing drugs to control pain in patients with chest injuries. Intercostal nerve block is the method of choice. This has the great drawback of short duration and at times must be repeated frequently. The effect may be prolonged by making the injection as close to the nerve root as possible and by blocking the third through the twelfth nerves. Complete blocking of the injured side of the chest will very often relieve distressing dyspnea and cyanosis by overcoming the splinting caused by pain. The relief of cyanosis and dyspnea by intercostal nerve block has at times been dramatic. The spasm of upper abdominal muscles is often relieved by this procedure and this fact has been helpful in ruling out penetration of the abdomen in conjunction with a chest wound. Small doses of codeine sulfate combined with one of the barbiturates are helpful in providing rest and pain relief. Morphine is almost never necessary when intercostal nerve block is available.

FIG. 3.—Large tube closed drainage. The rubber cuff sutured to the skin with heavy silk maintains the position of the drainage tube.

FATALITIES

There were three deaths in the 402 cases, a mortality rate of 0.9 per cent. It is possible that other deaths may have occurred subsequent to evacuation from the hospital, but at the time of evacuation there were no patients in whom such a possibility was other than remote.

ABBREVIATED CASE REPORTS OF FATALITIES

Case 1.—A soldier suffered a perforating wound of the left chest, which was treated by débridement and aspiration at a Forward Hospital. He arrived at this hospital on the eighth postoperative day, was ambulatory from the following day until his sudden death on the fourteenth postoperative day. The cause of death at autopsy was pulmonary thrombo-embolism, the source of which was found to have been in the pelvic veins.

Case 2.—A soldier suffered a penetrating wound of the left humerus and left chest. For tactical reasons he was brought to this hospital by ambulance the day after injury, with continuous oxygen administration *en route*. After multiple transfusions, operation was performed on the second day. Thoracotomy, with removal of clot, a metallic foreign body and in-driven rib fragments, was done. His course was stormy, and he expired on the seventh postoperative day with progressive oliguria. There had been no obvious transfusion reactions. At autopsy, aside from local wound findings, the important lesions

were in the kidneys. The pathologist reported the presence of severe tubular degeneration, and "hemoglobinuric nephropathy." This is the picture seen in so-called "transfusion kidneys."

Case 3.—A civilian suffered a perforating gunshot wound of the left chest, diaphragm and kidney. The kidney was shattered and was removed through a transdiaphragmatic approach. Progressive oliguria and uremia ensued, and he died six days after operation. Clinically, there was no evidence of intrapleural or peritoneal infection. Autopsy was not permitted and the condition of the remaining kidney could not be determined.

DISPOSITION OF CASES

The following table indicates the disposition of the 402 cases. The only definite end-results are the three deaths. We have mentioned the fallacy of "returned to duty" as an end-result. There are two larger groups in which we can do no more than state that, in our opinion, the chest lesions were healed; but because of other injuries or the need for further convalescence, it was necessary to evacuate them to the Zone of Interior or to rear echelons in the Zone of Communications. So far as the chest lesion alone was concerned, it was our opinion that no further surgery would be needed and that complete recovery could be expected. This is obviously open to criticism. It is certainly possible that retained intrapulmonary foreign bodies which we considered innocuous, may prove to be otherwise, or may perhaps be removed with the thought of preventing further damage. A small group has been listed as unknown, and comprise patients who were in the hospital for a too brief period to permit speculation as to their future course. It should be said that the majority of these were either prisoners of war or members of other Allied Forces.

I. Cases which will probably require no further thoracic surgery			359	89.3%
a. Returned to duty	63	15.6%		
b. Evacuated to ZI	121	30.0%		
c. Evacuated to CZ	175	43.5%		
II. Other dispositions			40	9.8%
a. Evacuated—will need further thoracic surgery	8			
b. Evacuated because of cardiac damage	3			
c. Evacuated unknown	29			
II. Deaths			3	0.9%

SUMMARY AND CONCLUSIONS

(1) A study of 402 cases of penetrating or perforating chest wounds treated in a General Hospital during campaigns in Italy and France is presented.

(2) A low incidence of empyema, clotted hemothorax, operative procedures necessary and a low mortality rate are shown.

(3) It is suggested that early, frequent aspiration, adequate blood replacement and early ambulation are extremely important in the reduction of the incidence of complications.

(4) It is further suggested that definitive treatment of penetrating chest

wounds may be carried out most satisfactorily in the Forward General Hospitals.

REFERENCES

1 Nicholson, W. F., and Scadding, J. G.: Lancet, **2**, 299–303, March 4, 1944.

2 Churchill, E. D.: ANNALS OF SURGERY, **102**, 268–283, 1944.

3 D'Abreu, A. L., Litchfield, V. W., and Hodson, C. V.: Lancet, **2**, 197, 1944.

4 Burke, J., and Jacobs, T. T.: Submitted for publication to Archives of Surgery, October, 1944. Published Nov., 1945.

5 Jacobs, T. T., and Burke, J.: ANNALS OF SURGERY, **123**, 48–52, January, 1946.

6 Leahy, L. J.: J. A. M. A., **114**, 868–869, March 9, 1940.

THORACIC GASTRIC CYST

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THERE is a great variety of cysts which occur in the mediastinum. One of the more unusual types is of entodermal origin—the gastric cyst. We have found only 16 cases in the literature (Table I) and the rarity of the condition seems to justify this case report.

Case Report.—M. C., a 22-months-old white female child, was admitted for the first time to the University of Virginia Hospital, May 3, 1945, with a history of pulmonary symptoms since shortly after birth.

The patient was born in another hospital, of normal parents, after a normal pregnancy and uncomplicated delivery. She was the first of three children, apparently normal twins being born about one year later. The patient's first two weeks of life while still in the hospital were uneventful, but soon after she was taken home she developed symptoms of a "cold," with a slight cough, nasal congestion and low grade fever. These symptoms persisted until the age of four months when she began to have severe paroxysms of coughing accompanied by cyanosis. Her voice became hoarse, and a diagnosis of "membranous croup" was made by the family physician. A chest film at that time is said to have revealed evidence of pneumonia. These symptoms, wet paroxysmal cough, fever, hoarseness and episodes of cyanosis continued despite several courses of sulfonamide therapy. Serial chest films revealed what was interpreted as a chronic pneumonia on the right side, which, in view of the prolonged illness, was finally decided by her local physician to be a lipoid pneumonia. At the age of seven months, the patient coughed up a large quantity of bright blood, estimated at one pint by the mother. Smaller hemorrhages occurred several times within the next three days. Clubbing of the fingers was noticed at this time by the mother. Since then, until admission to this hospital, seven severe pulmonary hemorrhages occurred, each requiring hospitalization and multiple blood transfusions. Only in recent weeks had the persistently wet cough resulted in the expectoration of grossly purulent sputum.

The child had not developed normally. She had been able to sit alone for several months but still could not stand alone, and had made no intelligible sounds. Her appetite was fairly good, but sleep was interrupted by frequent coughing attacks.

Physical Examination: Examination of the patient on admission revealed a fretful, poorly developed, undernourished, and obviously chronically ill child, weighing 18 pounds. The temperature, pulse and respiratory rate were normal. The skin was cold and moist, and the hair was very scanty. Marked clubbing of the fingers and toes was present. The chest had an enlarged anteroposterior diameter, suggesting emphysema. Auscultation revealed coarse moist râles bilaterally from apex to base, the right side harboring the most marked signs. There was no appreciable dullness to percussion. The abdomen was moderately distended and the liver edge was palpable two centimeters below the costal margin. Nose and throat examination was negative except for much mucus in the pharynx. There were no palpable lymph nodes of significance.

Laboratory Studies: Uranalysis revealed a one plus albumin and 18–20 white cells per high power field of the centrifuged specimen. The hemoglobin was 14 Gm./100 cc., or 91 per cent (Haden). The red cell count was 5.81 million, and the white cell count was 19,000. The differential count of the white cells showed 44 per cent polymorphonuclear cells, 49 per cent lymphocytes, 5 per cent transitional monocytes, 1 per cent basophils, and 1 per cent eosinophils. (Three blood transfusions had been given the week prior to admission.) Stool examination was negative. The Shick and tuberculin tests were both negative. Culture of the sputum revealed a multiplicity of organisms, including *Staphylo-*

TABLE I

THORACIC GASTRIC CYSTS

(*Reported in the Literature*)

Author	Sex and Age	Functional Activity	Treatment	Result
1. Staehelin & Burckhardt, 1909	Female, 9 mos.	Inactive	?	Autopsy finding
2. Mixter & Clifford, 1929	Male, 22 mos.	Active	Drainage and excision	Good
3. Mixter & Clifford, 1929	Male, 7 mos.	Inactive	None	Autopsy finding
4. Smith, 1930	Male, 14 mos.	Inactive	None	Autopsy finding
5. Fischer, 1930	Female, 6 mos.	Inactive	None	Autopsy finding
6. Entz & Orosz, 1930	Male, 11 mos.	Inactive	Drainage	Died, verified at autopsy
7. Poncher & Miles, 1933	Male, 29 mos.	Active	Operation	Died on op. table
8. Boss, 1937	Male, 3 yrs.	Active	Operation	Died on op. table
9. Seydl, 1938	Female, 3 mos.	Active	None	Autopsy finding
10. Nicholls, 1940	Female, 3 yrs.	Active	Drainage and excision	Good
11. Schwartz & Williams, 1942	Male, 23 yrs.	Inactive	Excision	Good
12. Schwartz & Williams, 1942	Male, 4 mos.	Active	Excision	Died
13. Carlson, 1942	Male, 4 mos.	Active	Excision	Good
14. Wyllie & Pilcher, 1943	Female, 12 mos.	Active	Excision	Good
15. Olken, 1944	Male. newborn	?	None	Autopsy finding in stillborn
16. Laipply, 1945	Male, 27 hrs.	?	None	Autopsy finding
17. Valle & White, 1945	Female, 22 mos.	Active	Operation	Died on op. table

coccus aureus nonhemolyticus, *H. influenzae*, unidentified micrococci, *Streptococcus viridans*, and a yeast-like organism never fully identified but apparently nonpathogenic.

Roentgenologic Examination: Roentgenograms of the chest revealed a marked mottled infiltration particularly in the right lower lobe but with some involvement also in the middle and upper lobes. There was a dense elliptical shadow in the right hilar region which was thought to be an enlarged hilar lymph node. No evidence of cavitation was seen. The left lung was essentially clear. A review of the old films taken at intervals since the patient was four months old disclosed similar hilar adenopathy and infiltration in the right lung.

Bronchograms revealed generalized bronchiectasis of the right lung and a large cavity in the posteromesial portion of the right lower lobe. The oil flowed readily into this cavity through a large bronchial communication (Fig. 1). The left side was normal.

Laryngoscopy and bronchoscopy were performed on May 8, 1945. The true vocal cords were reddened and edematous, but the movements were normal. The mucosa of the trachea and right bronchial tree was also subacutely inflamed and copious mucopurulent secretions were aspirated. The left bronchial tree presented a mild inflammatory reaction with a small amount of secretion. There was no evidence of foreign body, tumor or stenosis.

The diagnosis of bronchiectasis with an infected bronchial cyst was made. Since the condition seemed to offer a threat to life, surgical extirpation of the diseased lung was advised in spite of the poor general condition of the patient.

Operation.—May 14, 1945: One of us (A. R. V.) explored the right chest through a long posterolateral incision, entering the pleural space through the periosteal bed of the resected seventh rib. The pleural space was partially obliterated by numerous adhesions but no difficulty was encountered in mobilizing the lung except in the posterior gutter where the lower lobe was very densely adherent. Just above the diaphragm in the lower lobe there was a dense mass, apparently inflammatory, about the size of a hen's egg. This mass was presumed to represent the cystic area seen roentgenographically. With much difficulty this portion of the lung was separated from the parietal pleura, but in so doing the cystic cavity was broken into and the peripheral portion of the cavity wall, densely attached to the diaphragm and posterior gutter, remained behind as the mobilization of the lung was completed. The lung itself was obviously infected, there being areas of dense inflammatory infiltration from apex to base. Pneumonectomy seemed justified and feasible. Hilar dissection was attempted but enlarged hilar lymph nodes

and friable inflamed tissues rendered impossible the individual isolation of the vessels and bronchus. Therefore, the Shenstone tourniquet was placed around the hilar structures, and a transfixion suture of heavy silk was used to ligate the hilum *en masse*. The lung was then amputated. After release of the tourniquet, the bronchus and vessels were individually treated, the former with fine silk sutures and the latter with silk ligatures. The stump was covered with mediastinal pleura. At this stage in the operation the heart suddenly stopped, as if from vagal stimulation, and all attempts to initiate

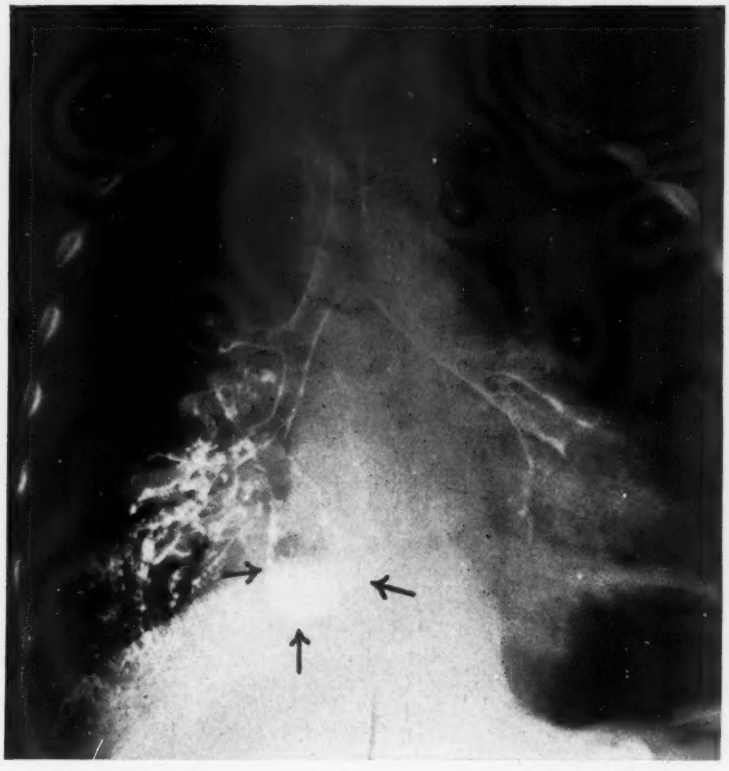

FIG. 1.—Bronchogram showing cyst communicating with the right lower lobe bronchus. Arrows outline the cyst which is partially filled with iodized oil.

pulsations by constant massage and medications for 20 minutes were of no avail. Spontaneous respiration ceased several minutes after cardiac arrest.

It had been our plan to remove the remainder of the cyst wall from the diaphragm and posterior chest wall after the lung had been removed. Postmortem dissection on the operating table of the remaining portion of the cyst proved that complete excision would have been an impossible surgical feat. Closer examination of the lining of the cyst suggested typical gastric mucosa with rugae, and the true diagnosis was first suspected at this time. Further dissection found the remnants of the cyst to extend down through the diaphragm, in intimate contact with the inferior vena cava, the bodies of the vertebrae and the esophagus. Adjacent inflammatory tissue necessitated sharp dissection throughout, and even with the utmost care in order to preserve the specimen the inferior vena cava was entered. The cyst ended blindly about five centimeters below the diaphragm, without anatomic continuity with either esophagus or stomach.

Pathologic Examination: The specimens consisted of an infant's right lung and an irregular piece of tissue, measuring 11 x 5 centimeters. The external appearance of the lung revealed extensive pleural adhesions and a small cavity communicating with

the posterior portion of the right lower lobe. When the lung was sectioned, dilated bronchi were found throughout. A probe passed into the cavity easily entered a branch of the right lower lobe bronchus. The separate piece of tissue grossly resembled stomach wall, having a mucosa with characteristic rugae and apparent muscular layers. The cavity in the lower lobe mentioned above had a similar mucosal pattern.

Microscopic sections revealed bronchiectasis, subacute bronchitis and areas of pneumonitis throughout the lung. Sections through the cyst wall showed the elements of a normal stomach, with typical mucosa and muscular layers (Figs. 2, 3 and 4). One section taken through the bronchial communication with the cyst shows the juxtaposition of the gastric mucosa with the elements of the bronchial wall (Figs. 2 and 4).

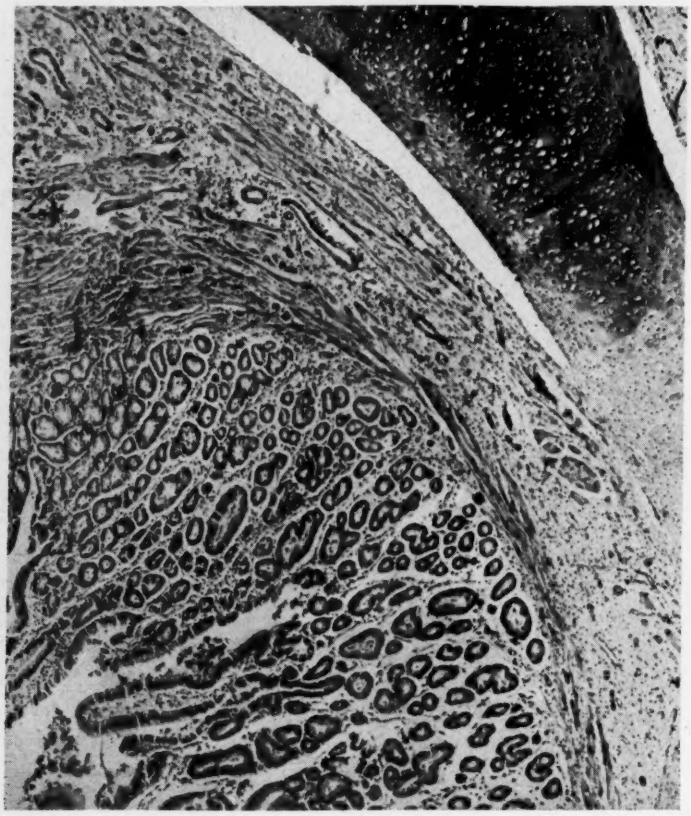

FIG. 2.—Photomicrograph showing typical gastric mucosa and bronchial cartilage.

COMMENT: There are two kinds of gastric cysts, those that are acid-secreting, or functionally active, and those of which the mucosa is without functional activity. Even though the acidity of the cystic secretions was not determined in our case, the early manifestation of symptoms—primarily hemorrhage, is so typical of the proven functionally active cases in the literature, that we feel justified in classifying this case as an acid-secreting or functionally active cyst.[10] From a review of the literature, it is found that there are two constant characteristics of a gastric cyst—it always occurs in the posterior mediastinum and on the right side. The functionally active cysts usually manifest themselves by symptoms at an early age, whereas the inactive

ones may be discovered accidentally in a routine chest roentgenogram later in life.[10]

There are several theories about the origin of endothoracic gastric cysts. They have been ascribed to a pinching-off of an evagination of the embryonic foregut, to an intrathoracic vestige of the omphalomesenteric duct, and to a proliferation of an entodermal germ cell of the esophagus capable of producing gastric epithelium.

The cyst wall has all the elements of the stomach wall. Smith,[12] and

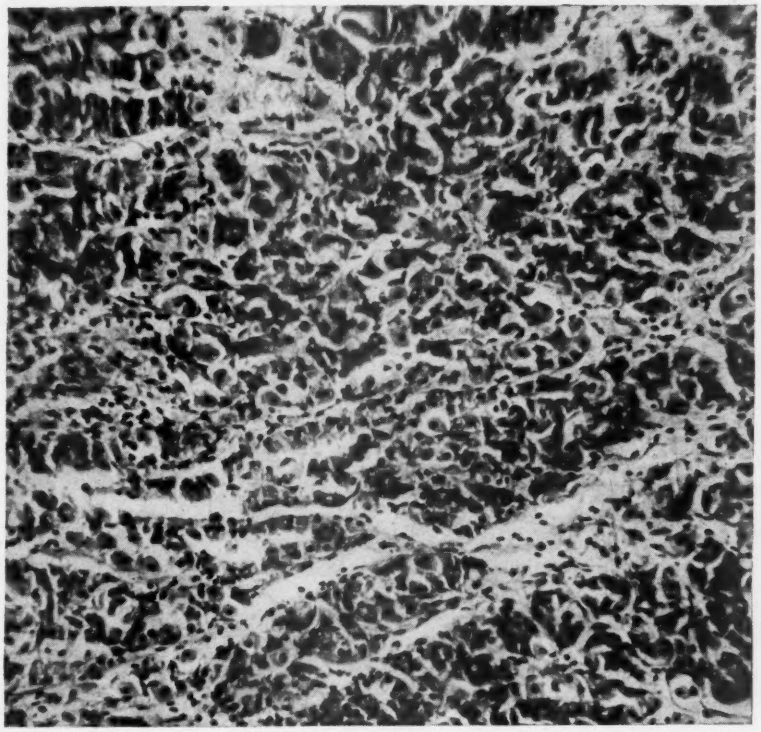

FIG. 3.—High power photomicrograph showing chief cells of the gastric mucosa of the cyst.

Staehelin-Burckhardt[13] have each reported a case which exhibited both gastric mucosa and ciliated stratefied respiratory epithelium in the same cyst. Boss[1] has described a case in which the intrinsic nerves and ganglia of the gastric musculature were identified. In our case, the cyst perforated the diaphragm and terminated in a blind sac about five centimeters below it. To our knowledge this feature has not been reported in the literature. It did not communicate with the stomach or the esophagus. Erosion of bone may be caused by the cyst, as reported in one of Mixter and Clifford's cases.[6]

The most commonly observed symptoms of gastric cyst are dyspnea, cyanosis, cough, dysphagia and sometimes, even in infants, hemoptysis. The most striking symptom of our case was the massive hemoptysis which necessitated admission to her local hospital on nine different occasions, with multiple blood transfusions during each period. Both Boss and Seydl reported

hemoptyses in their cases and attributed them to the presence of chronic peptic ulcers in the gastric cyst. In both cases the ulcers penetrated into the adjacent lung causing fatal pulmonary hemorrhage. Although no peptic ulcer could be demonstrated in the specimen from our case, it is probable that one had been present, since the cyst had eroded into the right lower lobe bronchus and was draining through the bronchial tree. Inasmuch as this

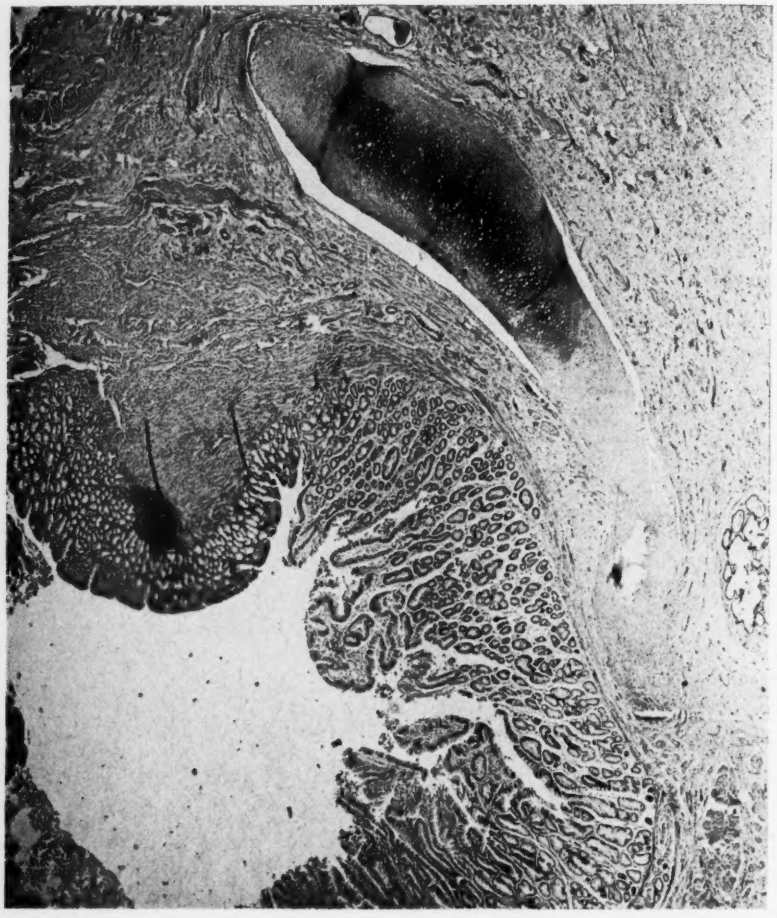

FIG. 4.—Low power photomicrograph of section taken at point where the cyst drained into the bronchial tree.

cyst was functionally active, the hemoptysis was probably due to bleeding from the ulcer itself and to the action of the gastric juice on the lung parenchyma and the bronchial tree.

The physical findings are variable but are usually those of pulmonary atelectasis or pneumonitis. There may be some cardiac displacement, scoliosis, or rarely, bulging of the chest. The findings in our case were primarily those of severe pneumonitis. The generalized bronchiectasis of the right lung, a complication resulting from the rupture of the cyst into the bronchial tree, has not previously been reported.

It is difficult to diagnose a gastric cyst during life with any degree of certainty without exploratory operation. However, the diagnosis is possible if gastric juice is aspirated directly from the cyst.[2] The cyst may contain from a few cubic centimeters of fluid to 400 cc. The fluid may be milky or clear, viscid or thin, or even sanguineous. The reaction is usually acid but may be neutral. Roentgenograms in both the postero-anterior and lateral projections are important, the lateral view particularly so, to show the cyst in the posterior mediastinum. Iodized oil bronchography is of use to show whether or not the cyst communicates with the bronchial tree and if so, to demonstrate its size, shape and location. In our case a diagnosis of posterior mediastinal cyst communicating with the bronchus complicated by generalized bronchiectasis of the right lung was made preoperatively. However, it was not until the typical gastric mucosa was seen when the cyst was opened at operation that the correct diagnosis was suspected.

The only treatment for gastric cysts is complete removal. If only a minute amount of the mucosa remains in the chest it will secrete and cause further complications such as empyema or a draining sinus, with or without excoriation of the skin. To date surgical treatment has not been too successful. Of the 17 cases summarized in Table I, ten had surgical treatment. Five of these survived, representing an operative mortality of 50 per cent. Two of these had a successful two-stage operation (drainage and later excision) and three had a one-stage removal. The high mortality is probably due to several factors. The patients are usually infants; they are usually in poor condition for a major operation; anesthesia is difficult to administer; and the dissection of the cyst from the mediastinum is technically impossible in some cases. The last factor is due probably to adjacent inflammatory reaction from the functional activity of the cyst. In some cases where complete removal of the cyst is impossible in a one-stage operation, preliminary drainage is useful as a palliative measure.

SUMMARY

A case of thoracic gastric cyst with certain unusual features has been reported. The cases reported in the literature have been summarized and a limited discussion has been presented.

REFERENCES

1 Boss, Carl: Virchows Arch. f. Path. Anat., **300**, 166, 1937.
2 Carlson, H. A.: Jour. Thor. Surg., **12**, 376, 1943.
3 Entz, B., and Orosz, D.: Frankfurt. Ztschr. f. Path., **40**, 229, 1930.
4 Fischer, Walther: Virchows Arch. f. Path. Anat., **275**, 711, 1929.
5 Laipply, T. C.: Arch. of Path., **39**, 153, 1945.
6 Mixter, C. G., and Clifford, S. H.: ANNALS OF SURGERY, **90**, 714, 1929.
7 Nicholls, M. F.:Brit. Jour. Surg., **28**, 137, 1940.
8 Olken, H. G.: Am. J. Path., **20**, 997, 1944
9 Poncher, H. G., and Milles, G.: Am. Jour. Dis. Child., **45**, 1064, 1933.
10 Schwartz, H., and Williams, C. S.: Jour. Thor. Surg., **12**, 117, 1941.
11 Seydl, Gunther N.: Frankfurt. Ztschr. f. Path., **52**, 346, 1938.
12 Smith, R. E.: Guy's Hosp. Rep., **80**, 466, 1930.
13 Staehelin-Burckhardt, A.: Arch. f. Verdauungskr., **15**, 584, 1909.
14 Wyllie, W. G., and Pilcher, R. S.: Arch. Disease Child., **18**, 34, 1943.

RESULTS FOLLOWING BANDS AND LIGATURES ON THE HUMAN INTERNAL CAROTID ARTERY

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IN THE SURGICAL TREATMENT of intracranial aneurysms it is at times necessary for the safety of the cerebral circulation to partially occlude the internal carotid artery as a preliminary step before total closure of the artery. For this purpose a band of fascia lata is preferable, although a band of dura or the fascial covering of the temporal muscle is equally effective. A partial ligation is necessary when the Matas test (digital pressure on the internal carotid for ten minutes) induces signs or symptoms of cerebral anemia and, therefore, indicates an inadequate collateral circulation at the circle of Willis. Reduction in the lumen of this artery (by a band) to one-half, or more, forces the collateral channels at the circle of Willis to enlarge and carry an additional load to the brain. In a week or ten days the resulting increased blood flow through the circle of Willis is sufficient to permit total ligation of the internal carotid in the neck, or intracranially, or both. In a group of patients in whom a band has been placed for this purpose and total ligation has later been necessary, the segment of the artery, including the band, has, at that time, been excised for gross and microscopic study, principally to learn what happens to the affected portion of the artery and to the band. Since the band is always applied just above the bifurcation of the common carotid it has been necessary to include in the resected segment of the internal carotid a small part of both the common carotid and the external carotid arteries.

The specimens for study are (1) those following partial ligation of the artery (six cases) (Fig. 1); (2) following total ligation of the internal carotid (one case), and total ligation of the common carotid (one case) (Fig. 2); and (3) a single case following ligation of the intracranial carotid by a silver clip (Fig. 2).

(1) Specimens following *partial* occlusion of the internal carotid by fascial bands (six cases):

There are six of these. In all of them the lumen of the internal carotid has remained patent, though greatly reduced in size. The intervals of time between application of the bands and removal of the specimens at operation were, 16, 18, 25, 27, 58 and 58 days. In only one was there any indication of a thrombus within the lumen; in this case the thrombus was a tiny non-obstructing caruncle-like fibrous nodule. This patient had highly sclerosed arteries and a high grade of hypertension. Whether this condition of the arteries or the band was responsible for the thrombus is impossible to determine, though it would appear logical to assume that the band was at least a determining factor because the thrombus was directly under it. However, the intima was not infiltrated with cellular reaction.

In all cases there was an excessive bulbous mass of fibrous tissue about

the bands. The size of the swelling increases with time, and at the end of 58 days was perhaps four or five times larger than the original volume of the fascial band. In the specimens of 16 and 18 days the fibrous mass is about double the size of the original band.

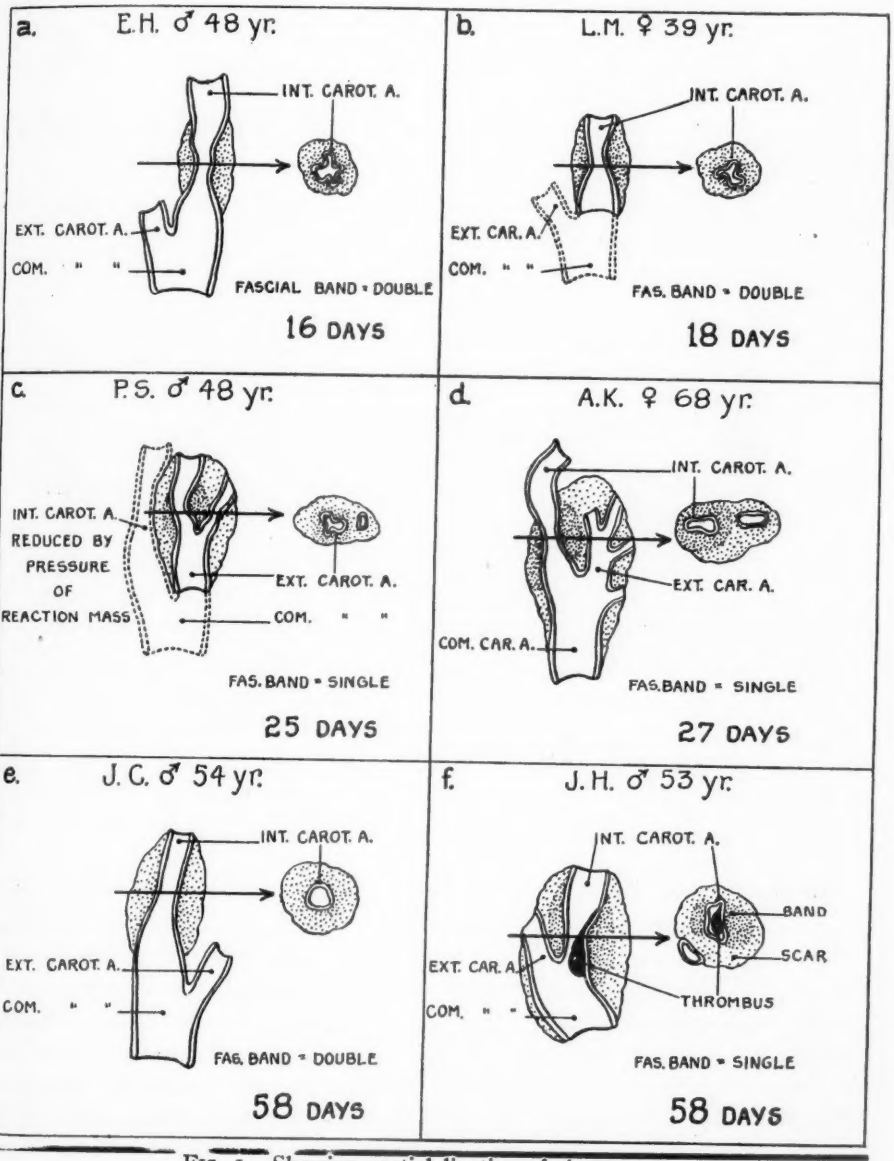

FIG. 1.—Showing partial ligation of the artery.

In all specimens the bands show marked fragmentation. Under the microscope the integrity of the bands is in large part lost in the gross and they are difficult or impossible to delineate in the older specimens. There appears to be a larger mass of fibrous tissue about the single than about the

double bands, and is probably due to the greater and more rapid disintegration of the single fascial layer from the arterial pulsation.

A rather surprising histologic finding is the absence of any reaction throughout the intima of the arteries, there being no tendency to vascular rupture (Fig. 3).

In five of the six specimens the cross-section of the vessel shows marked wrinkling of the inner lining (in the gross), but in one specimen (58 days) the lumen was almost perfectly circular (Fig. 1).

(2) Thrombus formation within the carotids following *total* ligations (two cases) (Fig. 2):

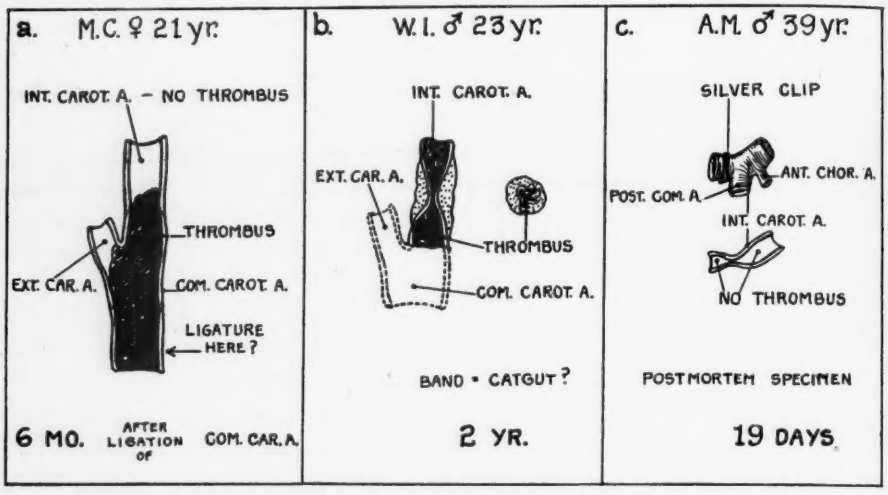

FIG. 2.—Two specimens in which (a) the common carotid artery; and (b) the internal carotid artery had been ligated, elsewhere, six months and two years, respectively, before removal of the segment of the carotid arteries; and (c) the results following the application of the silver clip to the intracranial portion of the internal carotid artery 19 days after its application. It shows absence of thrombus on either side of the clip. The extent of the intra-arterial thrombus following the total ligation is shown as far as could be determined from the examination at operation.

In one case the internal carotid had been ligated two years earlier (elsewhere), and in another the common carotid had been ligated six months before (elsewhere). In each, the vessel was thrombosed for a considerable distance. The extent was determined by palpation of the arteries and by opening the internal carotid. In the case of the previously-ligated *internal* carotid, the common and the external carotid arteries pulsated freely but the internal carotid was thrombosed higher than our exposure; the upper limit of the thrombus could, therefore, not be determined (Fig. 2b). In the case of total ligation of the *common* carotid six months earlier, the common carotid was totally occluded lower than our exposure and about two centimeters into the internal carotid: when the internal carotid was opened at this level there was bleeding from the cranial end but none from the cardiac end, which was full of firm thrombus; the external carotid was patent up to the bifurcation (Fig. 2a). In this case there was extensive new endothelial-

lined vascular spaces within the thrombus, but there is no evidence that they were continuous and the absence of bleeding proves that they were not.

It is clear from these two cases that the extent of an intra-arterial thrombus resulting from total ligation of an artery is variable and unpredictable and is *not,* as has been frequently stated, limited by "the first sizable branch" (the external carotid).

(3) The single specimen taken 19 days following application of a silver

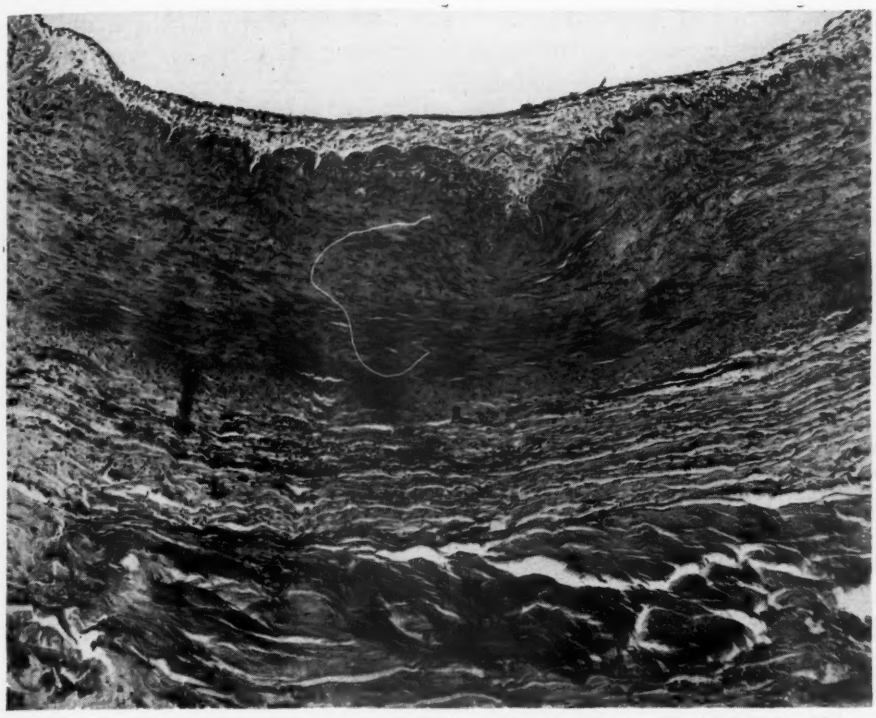

FIG. 3.—Photomicrograph 58 days after application of the fascial band. None of the coats show signs of necrosis. The elastic membrane is intact. The fascial band on the exterior is considerably fragmented. (x 60)

clip to the internal carotid is included because there was no thrombus on either side of the clip (Fig. 2c). This we have observed on at least four other occasions when the site of the clip has been subsequently exposed at a second operation; we were surprised to find the vessel patent both above and below the clip. That a thrombus is consistently absent after the application cannot, of course, be stated without many more observations. However, in a series of 38 intracranial "clippings" of the internal carotid there has never been clinical evidence of cerebral thrombosis. The absence of thrombus formation within the artery in this experiment is exactly the same as the results obtained by Doctor Halsted in a large series of dogs when aluminum bands were used. The flat silver clip is doubtless comparable in its action to that of an aluminum band on the internal carotid in the neck. And when the greatly reduced size of the intracranial portion of the internal carotid is

considered, the size of the silver clip is relatively the same as the larger band in the neck.

TYPES OF BANDS

In 1905, Professor Halsted made extensive studies on the aorta and carotid with bands of different kinds. He gave up fascia lata because it disintegrated rapidly under the pulsation of the vessel. His final choice was an aluminum band for which a specially contrived roller placed the band around the vessel in a cylinder. It was then moulded with the finger until the desired degree of partial constriction or total occlusion was attained. From these studies several fundamental principles for vascular surgery were made, and have since remained unchallenged:

(1) Whether the band is partially or totally occluding there is no thrombus formation within the arterial lumen.

(2) Thrombus formation is due to injury to the intima by ligation (this was known before).

(3) Beneath an aluminum band the vascular wall becomes completely necrotic.

In his earlier experiments (1905) Doctor Halsted stated that under partially constricting bands the wall of the vessel did not become grossly necrotic after ten days. In his last published paper (1924), however, he stated that "the included portion of the wall always dies whether the occlusion is *partial* or *complete.*"

Reid (1916) carried on another series of experimental studies for Doctor Halsted, using bands of various metals, and concluded that the wall of the artery always atrophied beneath the band. This was the investigation that changed Doctor Halsted's opinion on this point. In the earlier experiments he had not made microscopic examinations of the arterial walls.

Matas (1911) used aluminum bands on the big vessels for occlusion of the carotids, because it could be safely removed if the cerebral circulation should be inadequate. An ordinary ligature would cut through all the coats and, therefore, could not be removed without danger of rupture. He also demonstrated that necrosis of the vessel was not visible until 96 hours after the band had been applied. He has since had occasion to remove the bands from the carotid in several instances, and with return of cerebral function. An interesting case of C. H. Mayo's was referred to by Doctor Matas in this early publication: A patient upon whose carotid a thin tin band had been applied developed cerebral symptoms (loss of vision); he loosened the band but did not remove it; the vision returned and the band healed in place. Doctor Matas emphasized the fact that a ligature could not have been removed.

Since this publication the invaluable Matas test for the efficiency of collateral circulation has been introduced, and when correctly applied, the surgeon no longer guesses but can know with certainty before operation whether or not a total occlusion will be tolerated. Doctor Matas, I think, still uses the metal band on the carotid because of the reputed disintegration of fascia.

Pearse (1932) titled a publication "The Impracticability of Using Fascia for Gradual Occlusion of the Large Arteries," and concluded that at that time Halsted's aluminum band was "the best device today." In a series of experiments upon the aorta of dogs the bands of fascia were found to disintegrate and relax even when six or eight thicknesses were used. In some instances the walls of the artery ruptured beneath the bands (25 per cent). He reasoned that fascial bands were unreliable and dangerous.

Despite the above experimental evidence bands of fascia lata have been used in all of our cases, and without an untoward result of any kind. They are sewn in place at the desired constriction of the artery after the method of Kerr (1925). They have served their purpose with complete satisfaction in a series of 30 cases to date.

The danger of rupture of the internal carotid from a viable tissue is, I think, less than from a metal band. Moreover, they are just as easy to remove if that should be necessary when the constriction has been carried too far. In three of our series the bands have been removed and later replaced with less reduction of the lumen. Complete cerebral function returned in two, and partially in a third.

In the microscopic sections the intima is always viable and unchanged from the normal, *i.e.,* it does not disintegrate as under an aluminum band. There is no doubt that the fascia does disintegrate (Fig. 4), even when doubled, but the doubling decidedly delays the fragmentation. However, this probably is not so important in the carotid because there is a greater mass of fibrous tissue about the single bands and is probably roughly proportionate to the disintegration. The volume of connective tissue produced about the band is doubtless an important factor in reinforcing the vessel. Certainly, in no instance has there been any tendency of the lumen to expand. On the contrary, I should guess that the mass of fibrous tissue probably gradually constricted the lumen farther than obtained at the time the band was applied.

Most of the experimental work has been done on the aorta—a very much more severe test for bands than the internal or common carotid. When a band is applied to the aorta there is no other sizable preformed channel by which the arterial load can be diverted to the lower part of the body. The anastomotic channels develop slowly through the dilatation of tiny communicating channels. After the carotid is tied, an increased volume of blood is immediately transferred to the other carotid and thence through the sizable trunks of the circle of Willis, which can quickly enlarge. I should not even suggest that fascial bands would be applicable to the aorta of human beings even when applied in multiple layers: but for the carotids the results are undeniable.

PROGRESSIVE OCCLUSION OF THE LARGE ARTERIES

A method by which a progressive constriction of a large artery could be induced has, until recently at least, been unsuccessful. Doctor Halsted's experimental efforts were originally begun with the hope that a partially occluding band could be still further constricted by a subsequent manipula-

tion of the band by reopening the wound, thus making the final occlusion by steps instead of gradually. All earlier attempts to induce progressive occlusion had been through ligatures or clamps that were left extruding from the wound, and these always became infected, with disastrous results. But Doctor Halsted's bands have not been satisfactory because the wall of the vessel became necrotic.

Pearse (1940) has recently introduced, in experimental studies, a very ingenious method of gradual compression of large vessels which may or may not prove to be the answer. A layer of cellophane is wrapped around the

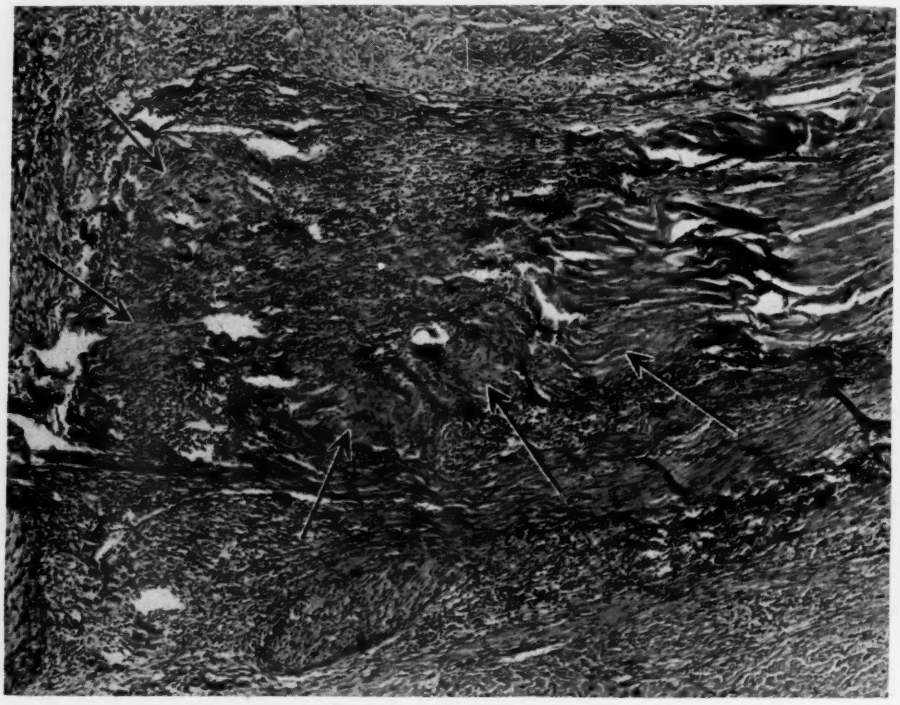

FIG. 4.—Photomicrograph showing marked fragmentation of the fascial band. The remains of the band are in small islands. This was a single band. The specimen was taken 58 days after the band was placed. (x 75)

aorta and tied: a violent and extensive cellular reaction (doubtless of chemical origin) engulfs the band and gradually constricts the vessel until it is completely closed. This fibrous mass has been strong enough to prevent rupture of the vessel. Its practicability in human cases has, I think, not been tested. Its use on the carotid artery may or may not be as good as fascia. It could hardly be better. At most, it could only make a subsequent total ligation unnecessary: and to do this would require a certainty in its efficacy which could only be acquired by an extended experience. Fortunately, in the carotid attack a progressive occlusion is not essential for success. Here, again, ligations of the carotid and of the aorta are entirely different problems: what applies to one does not apply to the other. It should also be noted

that the reaction to bands of fascia lata is precisely similar to those of cellophane except in degree. The mass of fibrous tissue is, at least, an effective support for the arterial wall and it may, and probably does, cause progressive occlusion of the lumen.

INTRACAROTID THROMBOSIS FOLLOWING BANDS AND LIGATURES

It is very probable, but not certain, that a thrombus always develops in time on either side of a *ligature* on a large arterial trunk. Our two cases are examples. This is doubtless due to injury of the intima, which must always occur. And yet bands of fascia and aluminum, whether partially or totally occluding, appear not to do this. Doctor Halsted's experiments with aluminum bands and ours with fascia are proof of this.*

The development of a thrombus after ligation and its absence following application of a band, are the reasons for a better form of ligation of the internal carotid. When a clot forms in the carotid it may break off and send an embolus into the cerebral arteries, with disastrous results; or the clot may propagate from the site of the ligature and pass directly into the cerebral vessels with the same result. Either of these eventualities is the explanation for the hemiplegias and deaths that occur 12–96 hours after carotid ligations. I am certain that they can be avoided either by totally occluding bands of fascia or by ligating *over* a band of fascia. The ligature does not then cut the intima. The latter procedure is probably preferable and more certain. One should never trust to a ligature directly applied to a large artery.

That injury to the intima of a large artery was responsible for thrombus formation is not a new conception. The following interesting excerpts from that great English master of surgery, Sir Charles Bell (1816), show how long this has been known. "I was taught carefully to avoid drawing a ligature so tight around an artery as to cut the inner coats; and this remark was repeated both in the dissecting room and the hospital." He then made some facetious remarks about theoretic surgeons who were trying to revolutionize the surgery of blood vessels, by tying the artery and at once removing the ligature. He predicted that some bright young surgeon would put it in practice and "it was done that winter," for an aneurysm of the leg. "But as it did not cure the aneurysm, the medical world heard nothing about it." "To correct this erroneous, because partial, view of the subject, I made the following simple experiment. I put a cord around the carotid of a dog without drawing it. The ligature lay in contact with the coats of the artery but did not press upon them, nor interrupt the flow of blood through them. I was certain of the result: a clot formed where the artery was irritated by the presence of the ligature and the vessel was obstructed at that part."—"the effect of the ligature is perfect." "After this experiment I should be as fully authorized to commit the folly of using a ligature to the artery of an aneurysmal

* It cannot be said that a thrombus will *never* occur, but in none of our cases has it been seen. However, in one case of his and one of mine there was a tiny nonpropagating, nonobstructing caruncle-like body in the lumen under the band, and presumably related to the band.

limb, thus, simply putting it around the vessel without tying it (Fig. 5), as they who propose to effect the same purpose by cutting the coats of the vessel with the ligature and taking it off again"—and concludes that "a surgeon ought never to consider himself at liberty to deviate from a line of practice which experience has taught to be effective and safe."

One cannot be certain to whose new experimental studies Bell referred, but just at that time three important contributions were made in England on the use of ligatures on large arteries. They were by Jones (1802), Travers (1813), and Lawrence (1815), and doubtless these stimulated his sarcastic remarks. The particularly pertinent experimental studies of Travers had just appeared and very probably provoked his attack.

Jones showed that (1) a tightly drawn ligature always cut the two inner coats, only the adventitia holding fast. (Jones says this was known to Desault and was demonstrated to him [Jones] by Thomson, a surgeon in Edinburgh); and (2) a plastic exudate "lymph from the vasa vasorum" at the site of and induced by the ligature was responsible for the closure of the artery.

Travers found that after 12 hours a ligature performed no function because the reparative processes induced by injury to the vessels caused its permanent closure and, therefore, "it seemed probable" that the ligature could be removed after that time and the "dreaded inflammations" induced by the foreign body, *i.e.*, "liberation from the vessel by an ulcerative process" could be avoided. It will be recalled that at that time the long sutures were left emerging from the wound and were later (2–3 weeks) sloughed out.

Lawrence then introduced silk as the ligature of choice and began the unorthodox method of cutting the ligature close to the knot, leaving it to be disposed of by nature. Many of the wounds healed by first intention, but he was at a loss to understand what eventually happened to the ligature. Shortly thereafter the absorbable suture was introduced by Physic, of Philadelphia.

The relation of thrombus formation to ligatures has long been disputed. It was long ago proposed that it was responsible for the closure of the artery. Travers decried its importance saying it was variable, "it may be present in 12 hours and may not be formed in 24 hours." Senn (1885) found it to occur (as did Pouteau over a century before) only at times. He quoted Porta, one of the earliest great names in experimental vascular surgery, as finding thrombi in 87 per cent of the ligations, and Schumann in 33.3 per cent. Delpine and Dent (1891) found, in a series of sheep, a distal thrombus in only one and peripheral in all. Ballance and Edwards (1891) reported a thrombus in every instance, whether the intima was injured or not.

In retrospect, it is now clear that the thrombus above and below Bell's non-constricting band was due to infection which, of course, he could not know. The same explanation doubtless holds for the results of Delpine and Dent, and of Ballance and Edwards (1891), whose experiments were performed before Lister's discovery had taken effect.

Doctor Halsted's experiments, performed under strict surgical asepsis,

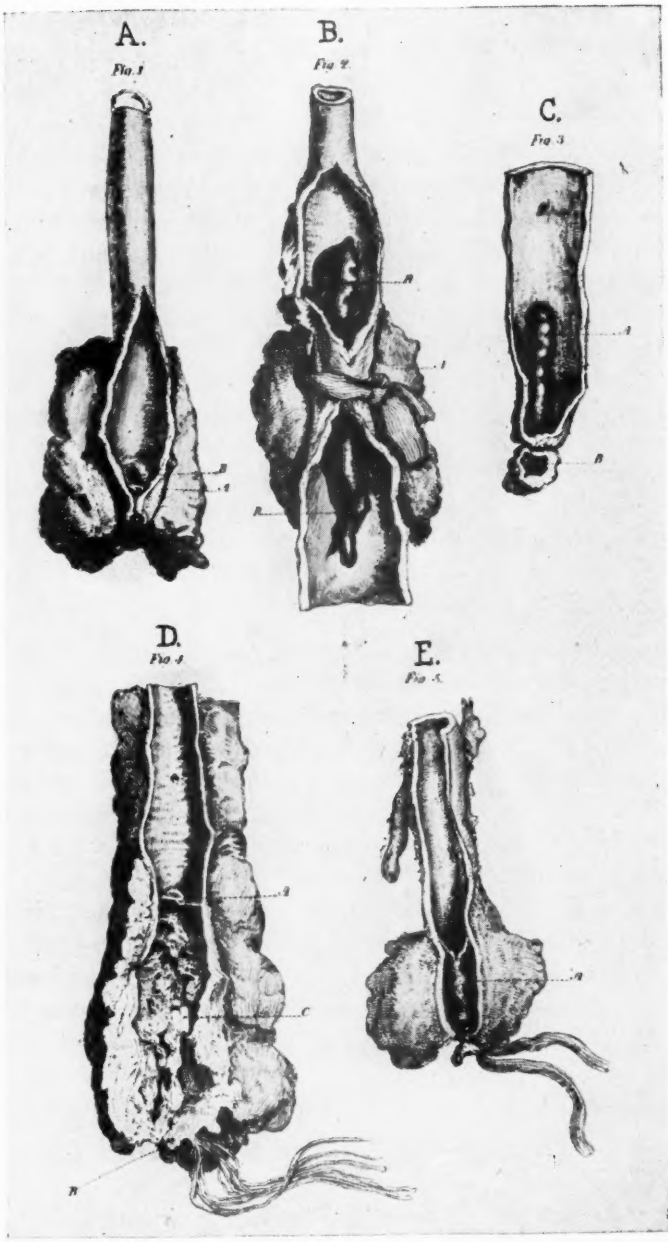

FIG. 5.—Plate retouched from Sir Charles Bell, 1816: These figures show principally the development of thrombi within the artery. Figure B is particularly interesting since a large ligature was placed around the vessel without constricting it, a clot forming, nevertheless. This was, of course, due to infection, a cause that was not known at that time. The proliferation of tissue around the ligatures is shown in Figures A, B and D. Figure D shows "the coats of the artery included in the common cellular tissue."

gave the answer when sepsis was excluded, and our human cases are exactly the same.

The conception that a thrombus ended at the nearest sizable branch, probably dated from Jones' experiments (1802). Soon thereafter, Travers (1813) emphatically stated that the thrombus "is not bounded by collateral branches but extends into them." Ballance and Edwards also concluded that "the length of the clot, either above or below the ligature, is not dependent upon arterial branches into and beyond which the clot may not pass." In Figure 5 (Bell's plate, Fig. 1) Bell's sketch shows a small thrombus at the site of the ligature and stopping at the mouth of an entering artery. Bell believed in this rather prevalent impression despite Travers experiments that denied it. In an earlier publication* I included a drawing of a spontaneous propagating and noninfective thrombosis that covered the entire course of the internal carotid and passed through the anterior and middle cerebral arteries and the posterior communicating arteries. One of the cases (Fig. 2a), here reported, shows that the external carotid was no barrier to its progress, and in the other case (Fig. 2b) the thrombus stopped part way up the internal carotid where there was no branch.

SUMMARY

(1) Six specimens of the human internal carotid were removed at operation for microscopic study at varying periods of time (from 16 to 58 days) after partially occluding bands of fascia lata had been placed on the vessels. Two specimens of the same vessel were studied for the extent of propagation of intra-arterial thrombosis following total occlusion of the internal carotid in one case and of the common carotid in the other. A specimen of the intracranial internal carotid was removed at necropsy 19 days after a silver clip had totally occluded the artery.

(2) Bands of fascia lata, either single or double, were used in these and 24 additional cases, and were perfectly satisfactory in every way.

(3) Although the bands disintegrate, a dense mass of connective tissue surrounds the fascia and prevents the artery from reëxpanding. Whether this mass of connective tissue produces an additional *progressive* constriction of the artery is not certain.

(4) The arterial wall does not become necrotic under the fascial band; as it does under an aluminum band. The intima is unchanged and shows no cellular reaction.

(5) Except for one tiny caruncle-like localized and nonoccluding thrombus in an elderly person with very sclerotic vessels there was no thrombus formation.

(6) In one patient whose *internal* carotid had been completely ligated (elsewhere) two years earlier, the thrombus completely filled the internal carotid higher than our incision in the neck but the common and external

*Zentralblatt für Neurochirurgie, 1937.

carotid arteries were patent. In the other patient, whose *common* carotid had been ligated (elsewhere) six months earlier, the common carotid was thrombosed lower than our exposure; the external carotid was patent and the thrombus in the internal carotid extended about two centimeters above the bifurcation, after which the artery was patent (it was divided at this level). The latter case demonstrates that the termination of a propagating thrombus is not determined "by the nearest sizable branch."

(7) The single case of a "clip" totally occluding the intracranial portion of the internal carotid, demonstrates the absence of an intra-arterial thrombus 19 days after application of the clip. In at least four other cases that have had reëxploration of the intracranially-clipped carotid (in carotid cavernous arteriovenous aneurysms) the absence of a thrombus on either side of the clip has been demonstrated by palpation of the vessel. This is, therefore, a disadvantage, when thrombus formation is desired to cure the aneurysm.

BIBLIOGRAPHY

Ballance C. A., and Edmunds, W.: A Treatise on the Ligation of the Great Arteries in Continuity. London, Macmillan & Co., 1891.

Dandy, W. E.: Carotid-cavernous Aneurysms. (Pulsating Exophthalmos) Zentralblatt für Neurochirurgie, **2**, Jahrgang No. 2, 1937.

Dandy, W. E.: Results Following Ligation of the Internal Carotid Artery. Arch. Surg., **45**, 521, 1942.

Dandy, W. E.: Intracranial Arterial Aneurysms. Comstock Publishing Company, Cornell University, 1944.

Delpine, S., and Dent, C. T.: The Changes Observed in the Healthy Medium-sized Arteries and in Tendon Ligatures during the First Four Weeks after Ligation. Med. & Chir. Trans., **56**, 367, 1891.

Halsted, W. S.: The Partial Occlusion of Blood Vessels, Especially of the Abdominal Aorta. J. H. H. Bull., **14**, 346, 1905.

Halsted, W. S.: Partial Progressive and Complete Occlusion of the Aorta and Other Large Arteries in the Dog by Means of the Metal Band. Jour. Expt. Med., **15**, 373, 1909.

Halsted, W. S.: The Effect on the Walls of Blood Vessels of Partially and Completely Occluding Bands. Surgical Papers. The Johns Hopkins Press, 1924; 585.

Jones, J. F. D.: On the Process Employed by Nature in Suppressing the Hemorrhage from Divided and Punctured Vessels. Philadelphia, Th. Dobson, 1811.

Kerr, H.: Fractional Ligation of the Common Carotid Artery in the Treatment of Pulsating Exophthalmos. Surg. Gynec. & Obst., **41**, 565, 1925.

Lawrence, W.: A New Method of Tying the Arteries. Med. Chir. Trans., **6**, 156, 1815.

Matas, R., and Allen, C. W.: Occlusion of the Large Surgical Arteries with Removable Metallic Bands. J. A. M. A., **56**, 232, 1911.

Matas, R.: Discussion on Vascular Surgery: With Special Reference to Surgery of the Carotid Tracts. Am. Jour. Surg., **24**, 692, 1933.

Pearse, H. E.: The Impracticability of Using Fascia for Gradual Occlusion of the Large Arteries. Am. Jour. Surg., **16**, 242, 1932.

Pearse, H. E.: Experimental Studies on the Gradual Occlusions of Large Arteries. Trans. Am. Surg. Assn., **58**, 443, 1940.

Reid, M. R.: Partial Occlusion of the Aorta with the Metallic Band: Observations on Blood Pressure and Changes in the Arterial Wall. Jour. Exper. Med., **24**, 287, 1916.

Reid, M. R.: Partial Occlusion of the Aorta with Silk Sutures and Complete Occlusion with Fascial Plugs: The Effect of Ligatures on the Arterial Wall. Jour. Exper. Med., **40**, 293, 1924.

Senn, N.: Cicatrization of Blood Vessels After Ligature. Tr. Am. S. A., **2**, 249, 1885.

Travers, B.: Further Observations on the Ligatures of Arteries. Med. Chir. Trans., **6**, 632, 1815.

GASTRIC RETENTION AFTER POSTERIOR GASTRO-ENTEROSTOMY FOR DUODENAL ULCER: PREVENTION AND TREATMENT

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POSTERIOR GASTRO-ENTEROSTOMY for duodenal ulcer is a relatively safe procedure and in properly selected cases gives excellent results. It is not the operation of choice for patients who are less than 50 years of age, for most patients who give a history of severe hemorrhage, or for those who have actively inflamed lesions. But in that large group of elderly patients who have obstructing duodenal lesions, often associated with cardiac, pulmonary or cerebral complications, extensive gastric resection is too hazardous and posterior gastro-enterostomy is an ideal operation.

Two complications of this procedure have tended to cast it into some disrepute; namely, (1) gastrojejunal ulceration; and (2) postoperative retention of gastric contents.

Gastric retention after an operative change in the continuity of the upper gastro-intestinal tract is a perplexing and often serious problem. This interference with emptying of the gastric contents and the associated prolonged loss of fluids and electrolytes may lead to death. In less disastrous cases, there is still the expense of prolonged hospitalization and occasionally further operative procedures. The true incidence of postoperative obstruction is unknown but it is probably high. In fact, this complication has become such a bugaboo that sometimes ill-advised gastric resection rather than gastro-enterostomy is performed in an effort to avoid this embarrassing sequela. Ideally, the proper treatment of gastric retention would be its complete prevention.

The literature for the last 40 years on the subject of gastro-enterostomy is full of sanguine communications (and this paper perhaps will be so regarded), each of which purported to present some change in preoperative preparation, surgical technic, or postoperative care which prevented regurgitant vomiting. From a study of the literature and our own experiences, it would seem best for each surgeon to evaluate all suggestions and use that technic which in his hands produces the best results.

MATERIAL

During a three-year period, 200 consecutive cases in which posterior gastro-enterostomy had been performed for duodenal ulcer were observed. The first 100 cases (Group 1) showed such a distressing incidence of gastric

* Since this paper was written, Doctors Gray and Sharpe have entered the Armed Services, and are now Captain, Medical Corps, United States Naval Reserve, and Captain, Medical Corps, Army of the United States, respectively.

retention, necessitating further operation in six cases, that certain changes in operative technic and postoperative care were instituted. These principles were applied to the next 100 cases (Group 2).

The age and sex distribution, character of the lesion and temperament of the patients in the two groups were similar. The ratio of men to women

TABLE I

CLINICAL DATA IN TWO HUNDRED CASES

	Group 1 (100 Cases)	Group 2 (100 Cases)
Men	79	80
Women	21	20
Age, years:		
20–29	0	2
30–39	2	2
40–49	27	20
50–59	55	50
60–69	13	25
70–79	3	1
Youngest, years	30	29
Oldest, years	72	76
Average age, years	53.03	54.13
Pathologic lesion:		
Subacute duodenal ulcer	20	18
Chronic duodenal ulcer	22	9
Obstructing duodenal ulcer	58	73
History of bleeding	12	7
No retention	64*	81
Retention in men	32	17
Retention in women	3†	2
Retention for less than five days	11	6
Retention for more than five days	24	13
Further operation required	6	0
Longest hospitalization, days	78	23
Average days in hospital in excess of 14	13.8	3.9
Deaths	2‡	0

* One patient died three days after operation.
† One patient had serious retention.
‡ Mortality rate 1 per cent of 200 cases.

in both groups was about four to one (Table I). The youngest patient in Group 1 was 30 years of age, and the youngest in Group 2, 29 years. The oldest patients in the two groups were 72 and 76 years of age, respectively. The average age in both groups was essentially the same. Sixty-eight and 75 per cent, respectively, of the patients in these groups were between 50 and 70 years of age. The distribution of patients in the age-groups less than 50 and more than 70 years of age was essentially the same.

One surgeon (H. K. G.) selected the cases, using the same principles; superintended all preoperative and postoperative care and performed all operations, using the same anesthetic agent.

The changes in operative technic and postoperative care were the only variables in the two groups.

CAUSATIVE FACTORS

In general, retention of gastric contents after gastro-enterostomy may be divided into (1) the type that develops immediately after the operative procedure and progresses undiminished; and (2) the typical and more usual retention that develops between the seventh and tenth postoperative day.

The first type usually is the result of a mechanical disturbance which produces a malfunctioning or obstructed stoma. This disturbance has been ascribed by various authors to many causes, such as (1) a spur at the anastomotic site, occasioned by the festooning descent of the proximal and distal jejunal limbs; (2) the position of the anastomotic opening and direction of flow of peristalsis in the applied jejunum, whether isoperistaltic or retroperistaltic in relation to that of the stomach; (3) the long jejunal loop in the antecolic anastomosis which occasions filling of the proximal limb; (4) kinking of the duodenojejunal angle; (5) kinking or twisting of the distal limb of the jejunum as it leaves the gastric wall in an isoperistaltic anastomosis; (6) retraction of the anastomosis above the transverse mesocolon with angulation of the retracted jejunum; (7) peculiar valves of gastric mucous membrane or closure of the stoma by newly formed adhesions; (8) acute dilatation of the stomach; and (9) pressure on the jejunal limbs of the anastomosis by the middle colic artery if the anastomosis is made to the right of that artery.[7] Whatever the source, if the retention is caused by mechanical factors which manifest themselves immediately another operation is frequently necessary.

The second type of retention is less easily explained. It develops at about the time any severe gastrojejunal inflammation or edema of nutritional origin might occur, that is, between the seventh and tenth postoperative day. It is possible many times to predict at operation, on the basis of the patient's race, disposition, and temperament, the probability of postoperative retention. In these cases, the constitutional characteristics of emotionally unstable, high-strung, nervous persons become prognostic signs. Among the early theories of the cause of delayed retention are the presence of bile and alkaline juices in the stomach, an indefinite spasm at the stomal site and interference with innervation of the stomach and some disruption of peristaltic waves. At present, however, the consensus is that the obstruction is due either to a purely inflammatory gastrojejunitis or to edema of the stomal site, or most likely, to a combination of the two.

Postoperative gastritis probably extends beyond the new stoma. In the presence of an inflammatory process, delayed emptying of the stomach through the new opening into the distal jejunal limb is easy to understand. The presence of a certain degree of jejunitis in the distal limb is borne out by the fact that nearly all so-called gastrojejunal ulceration is in reality jejunal in origin. Most gastrojejunal ulcers are situated either in the distal limb of the jejunum or opposite the stoma on the jejunal wall.

Associated edema of greater or lesser degree is always present but probably is short-lived. As has been stressed for years by Ravdin, and others, it may be only part of a generalized edematous state occasioned by preoperative malnutrition, vomiting, restriction of fluids or anemia.

Ravdin, and others, have insisted that many patients are prone to have low plasma proteins after gastric operations as a result of a deficient preoperative diet. They have shown that these already diminished plasma proteins are lowered still further by the administration of saline postoperatively, with an

attendant increase in stomal edema. Enforced protein starvation due to the type of operation also supposedly increases hypoproteinemia. To combat this hypoproteinemia, Ravdin suggested early oral-jejunal feeding of amino-acids by the Abbott-Rawson tube. Chauncey, and one of us (H. K. G.), found, however, that the concentration of plasma protein is not the only cause of retention and is not the answer to the problem.

It has been suggested that, due also to faulty preoperative nutrition, certain vitamins are lacking in the blood stream and that this lack hinders healing of the stoma and promotes edema. Lanman and Ingalls showed that vitamin C is necessary for wound healing, and Thompson, Ravdin, Rhoads and Frank demonstrated that hypoproteinemia retards the healing of wounds. Vitamin B deficiency may lead to marked gastric atony and, indeed, such deficiency has been found in patients who have an atonic stomach without pyloric obstruction. Apparently the vitamin B complex as a whole is the necessary factor, for Heublein, Thompson and Scully were unable to demonstrate complete return of gastric tone by feeding vitamin B alone to patients deficient in the B-complex.

Obviously, there is no single cause for the distressing complication of gastric retention. A combination of all these factors is probably responsible, that is: (1) the personality, race, and temperament of the patient, his individual worries, *etc.*, (2) improper preoperative preparation, (3) the operative technic and (4) gastrojejunitis and edema of the stoma. The surgeon can do little to combat the first of these factors.

PREOPERATIVE PREPARATION

The preoperative preparation of patients who have duodenal ulcer has changed little since this study was begun and the patients in the two groups were prepared similarly. Transfusions of whole blood were given as necessary. In cases of pyloric obstruction, the stomach was emptied at least twice daily, and oftener if indicated. Fluids were given intravenously as necessary to replace this loss. These usually consisted of a solution of 5 per cent glucose in distilled water or 5 per cent glucose in a 1 per cent solution of saline. Vitamins in the form of thiamine chloride, brewers' yeast, ascorbic acid and haliver or cod liver oil were added.

OPERATIVE TECHNIC

Since Wölfler, at the suggestion of Nicoladoni, in Billroth's Clinic, first performed an anterior gastrojejunostomy and von Hacker a posterior anastomosis, both for carcinoma of the stomach, many different technics have been described.

The posterior anastomosis was used in the 200 cases in this series. The proximal limb of the jejunum was attached to the posterior wall of the stomach near the angle and the lesser curvature, and the line of anastomosis was extended downward and to the left, the distal limb leaving the wall of the stomach near the greater curvature, as suggested by W. J. Mayo, and others. The reasons for this position of the stoma seem sound.

Mayo's discussion of the anatomy of the region, 35 years ago, is appro-

priate still: "For convenience we will take the origin of the jejunum as being at the point in which the duodenum passes through the transverse mesocolon. The distal end of the duodenum lies behind the stomach when the latter is moderately distended and about one and one-half inches to the left of the middle line and one and one-half to two inches above the umbilicus. Its horseshoe-shape has its concavity directed to the left and upward and its exit is within about two inches as high as the pylorus. The transverse portion of the duodenum passes forward over the prominent vertebral column and backward to the left side of the spine to the opening in the transverse mesocolon. The terminal inch which marks the duodenojejunal juncture is directed upward and to the left, the mesentery of the proximal jejunum lying behind and the free surface of the intestine directed forward. The jejunum from its origin drops at once into the left abdominal fossa."

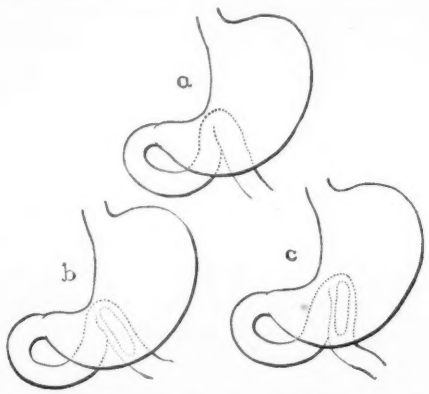

FIG. 1.—Relationship of first portion of jejunum to posterior wall of stomach: (*a*) normal; (*b*) gastro-enteric stoma made in location suggested by W. J. Mayo (1906), so as to avoid any distortion of the loop of jejunum proximal and distal to the anastomosis: (*c*) vertical gastro-jejunal stoma (slightly isoperistaltic) showing tendency to distortion of loop of jejunum proximal and distal to stoma.

This is important for two reasons. In the first place, if the jejunum is merely picked up and allowed to lie across the posterior wall of the stomach in its normal course it crosses the stomach from the patient's right and from above diagonally downward and to the left (Fig. 1*a*). If the anastomosis is made in this line, there is no angulation or distortion of the distal limb (Fig. 1*b*). If the anastomosis is more nearly vertical or isoperistaltic, running from above and downward to the right, angulation and distortion of the distal limb seem inevitable (Fig. 1*c*). In the second place, the fact that the jejunum drops at once into the abdominal fossa and even backward into the left kidney region emphasizes the necessity of carefully replacing the distal limb of the anastomosis behind and to the left of all other loops of intestine at the completion of the operation.

In speaking of the jejunum, Mayo continued: "Not only does it pass to the left but it gravitates backward into the left kidney pouch underneath the

splenic flexure of the colon, so that at a point four inches from its origin it lies on a plane to the left and posterior. This can be shown in a very practical way by drawing the transverse colon out through the abdominal incision, pulling it upward and to the right until the mesocolon is taut. This brings the beginning of the jejunum into view. It will readily be seen, therefore, that if the attachment is made to the stomach so that the proximal portion of the gastrojejunostomy is to the left and above, and the distal portion is directed to the right and below, we have introduced two serious displacements." This point is illustrated by Figure 1*c*. "The jejunum," Mayo said, "no longer falls in the normal manner to the left and backward, but is artificially caused to pass not only to the right but forward as it must ride the vertebral column or the structures immediately contiguous." The great portion of the stomach which lies to the left of the pyloric antrum acts in a storage capacity. Its muscular action is much less forceful than that portion of the stomach bounded by the horizontal line of the lesser curvature above. Therefore, the right edge of the new stoma should begin near the angle of the lesser curvature and proceed downward and to the left (Fig. 1*b*). This placement of the stoma was used in all 200 cases discussed in this paper.

The difference in surgical treatment of these two groups of cases was entirely in the line of suture. The position of the stoma and the method of securing the completed anastomosis below the transverse mesocolon was the same in both groups; however, in the first 100 cases (Group 1) only two rows of catgut were used in the anastomosis. After placing the clamps and guide sutures a continuous catgut suture of No. 0 chromic catgut was placed in the serosa of both the stomach and jejunum. The stomach and jejunum were opened and a second posterior row of continuous catgut suture was placed, taking all layers of the intestine. Even with the utmost care small, denuded portions unprotected by mucosa were left in the suture line. It was thought that such small surfaces perhaps were conducive to the development of gastrojejunitis, with its attendant edema. In the second 100 cases (Group 2), three rows of continuous catgut suture were placed, the first in the serosa, the second in the muscularis and submucosa and the third in the mucosa alone, taking care to protect the entire line of suture with mucosa, as suggested by Eusterman and Balfour (Fig. 2).

The incision employed was usually a high right rectus type, splitting the rectus muscle. The stomach, pylorus and duodenum were examined and in all 200 cases it was decided to undertake a posterior gastro-enterostomy for duodenal ulceration. For purposes of orientation, Allis clamps were applied to the anterior gastric wall, one just at the angle of the lesser curvature and the other diagonally to the left at the greater curvature. The transverse colon was pulled upward and to the right, drawing the transverse mesocolon taut by retraction in all directions. The proximal loop of jejunum usually came into view, but if not it could easily be grasped at the ligament of Treitz. Even if it should come into view easily, it should be checked not only to make sure of its identity but to provide as short a proximal loop as possible. The posterior wall of the stomach presses on the taut transverse mesocolon

and the approximate direction of the stoma can be seen by pressure on the Allis clamps already placed. An avascular region to the left of the middle colic artery was chosen and the mesocolon was opened in a line slanting upward and outward and to the left with the colon being held upward as described. The posterior wall of the stomach with its applied Allis clamps

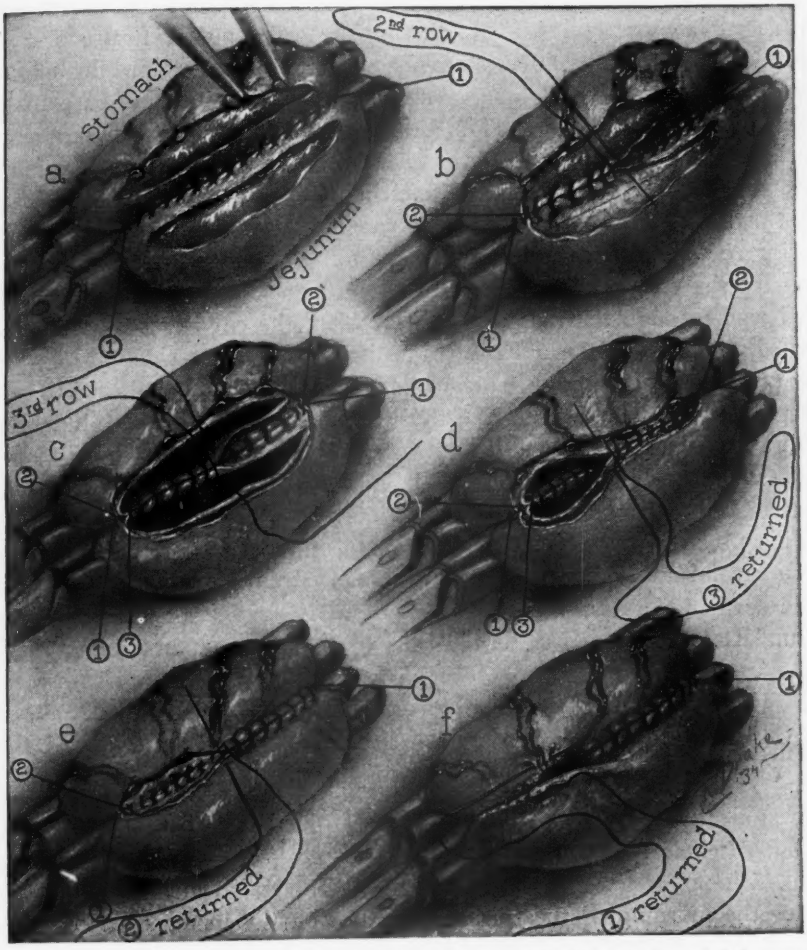

FIG. 2.—Steps in completion of the anastomosis of stomach and jejunum. The numerals indicate the order in which the rows of suture are made. ("The Stomach and Duodenum," by G. B. Eusterman and D. C. Balfour, W. B. Saunders Company, 1935.)

bulges through this rent and each clamp is removed from the anterior wall of the stomach and replaced in a similar position on the posterior wall. A straight rubber-covered clamp (Scudder) was placed on the stomach to include these clamps and to allow an anastomotic opening about 5 cm. in length. A similar rubber-covered clamp was placed on the jejunum, allowing 4 to 6 cm. for the proximal loop and making certain that the proximal loop of the jejunum was placed at the lesser curvature of the stomach. A

guide suture was placed at one end of the proposed anastomosis and the first row of continuous catgut suture was placed in the posterior row, using only the serosal layers of the jejunum and stomach, and leaving the suture long for use in returning across a similar layer in the anterior row. The gastric and jejunal walls were incised through the muscularis and submucosal layers to the mucosa itself and a second posterior row of continuous catgut suture was placed in these layers, again leaving the end long for future use. The mucosa was incised the full length of the anastomosis and a third line of suture approximated the mucosal layers of the posterior row, taking care to leave no raw, uncovered regions. This suture was returned in the first, or inner, anterior line. The rubber-covered clamps were loosened at this point to check any bleeding and the second anterior row of sutures was placed, using a continuation of the second posterior row. The placing of the third row of anterior serosal sutures finished the anastomosis (Fig. 2). At each angle one or two silk sutures were placed as reinforcement. The anastomosis was pulled well through the rent in the mesocolon, the cut edges of which were fastened with interrupted silk sutures to the wall of the stomach at least 2 cm. away from the anastomosis. The anastomosis should not be allowed to retract through the mesocolic opening and thus cause obstruction of the jejunal limbs. Finally, the entire anastomosis was carefully replaced in the abdominal cavity, making certain that the distal limb of the jejunum was well behind all other loops of intestine (Fig. 3).

This procedure was used in the second 100 cases. With the exception of the careful approximation of the mucosal edges with a third suture line, it was used in the first 100 cases likewise. No further operative procedure was undertaken in any case at the time of the gastro-enterostomy.

POSTOPERATIVE CARE

There was nothing unusual about the postoperative care in the first 100 cases. Adequate fluid intake was assured by either the subcutaneous or intravenous route, a 5 per cent solution of glucose in distilled water being the fluid of choice. A daily output of from 800 to 1,200 cc. of urine was maintained. Sips of water by mouth were allowed on the afternoon of the second day, or the morning of the third day and gradually increased. By evening of the fourth day the usual gastro-enterostomy feedings were tolerated and the intake of food gradually was increased. Aspiration of the stomach with the Levine tube was performed morning and night daily until the retained secretion was less than 150 cc. The inlying nasal suction tube was used only if retention developed. The patient usually was up on the eighth postoperative day and left the hospital on the 14th day.

The incidence of retention in the first 100 cases was distressing. In the second 100 cases, in addition to the difference in surgical technic, certain changes in postoperative care were instituted. The same principles of fluid balance and dietary management were observed. Aspiration was performed morning and night, as in the first 100 cases. The morning of the second day

the patient was given tablets of aluminum hydroxide gel (creamalin tablets) to chew slowly every three to four hours. As soon as water by mouth could be tolerated, neostigmine (prostigmine methylsulfate) was given to stimulate peristalsis and emptying of the stomach; 15 mg. of this drug was dissolved in 8 ounces (240 cc.) of water, and 2 ounces (60 cc.) of this solution were given four times daily. In those cases in which postoperative difficulty was anticipated because of the patient's temperament and racial characteristics, phenobarbital (luminal), 0.5 grain (0.032 Gm.), was given three times daily, and at the same time, atropine, 1/150 grain (0.00043 Gm.), or diphenyl acetic acid and diethylaminoethanol (trasentin), 75 mg. Since the retention usually developed on the seventh or eighth postoperative day, the amount of fluid taken by mouth was limited to 500 cc. from the seventh to the tenth postoperative day. A so-called dry gastro-enterostomy diet was allowed. The fluid by mouth never was taken with the feedings but rather between them. Subcutaneous infusion supplied the remainder of the necessary fluid intake on these days. In about the first 50 of these cases the stomach was aspirated morning and night of the seventh through the tenth postoperative day.

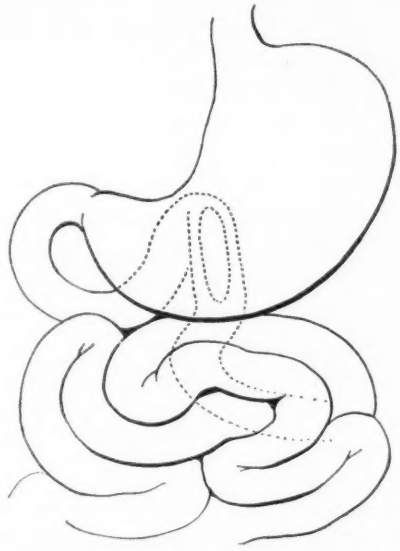

FIG. 3.—Relationship of the loop of jejunum distal to the stoma, and the remaining portions of the small bowel.

TREATMENT

No matter how carefully the prevention of gastric retention is planned, it occurs in a certain percentage of cases. However, the severity may be lessened by treatment. When gastric retention develops, the following treatment should be instituted: (1) Nothing should be given by mouth so that the stomach can have complete rest. (2) The fluid balance must be kept positive; that is, more fluids must be given parenterally than are excreted by the measurable urine and emesis output. The electrolytes lost by vomiting must be replenished. The ideal method, lacking a jejunal stoma and tube, is by subcutaneous infusion. Chlorides can be given thus, but glucose in solution must be administered slowly by the intravenous route. The amount and type of fluid given then depends on the output of urine and emesis and the levels of blood urea, carbon dioxide combining power of the serum, and blood chlorides as determined every second or third day. This equilibrium is easily disturbed and an alarming alkalosis or uremia quickly can develop. Frequent small transfusions of whole blood are beneficial. (3) Every effort

should be made to obtain normal bowel movements daily. Enemas may be given at first. One or two ounces (30 or 60 cc.) of castor oil may be left in the stomach by way of the aspiration tube after the tenth postoperative day. (4) The stomach must be emptied night and morning or oftener if necessary. No more than 300 to 400 cc. should be allowed to accumulate. If it becomes necessary to leave an inlying Wangensteen nasal catheter in place, constant suction should be avoided. If suction is used only 15 minutes of every hour, ample opportunity is provided for normal evacuation of some of the gastric contents, yet there is no danger of overloading the stomach. (5) Vitamins should be added to the intravenous solutions, particularly vitamins B and C. (6) Neostigmine (prostigmine methylsulfate), 1:2,000, may be given hypodermically, about 2 cc. four times daily.

If the principles already outlined concerning fluid balance are followed and the levels of the important chemical constituents of the blood are carefully checked, usually no operative procedure is necessary. If proper supportive treatment is given, the retention will clear up in most cases. However, in certain cases the blood chemistry values will vary from the normal range in spite of all efforts, and these patients will require further operation. The type of operation depends entirely on the condition of the patient and the ease with which the stoma, with its proximal and distal limbs, can be recognized. Many procedures have been recommended. Allen and Welch recently have emphasized the value of jejunostomy for the relief of a malfunctioning stoma. Jejunostomy alone is very effective, allowing the stomach to be put completely at rest. It is a relatively quick and easy procedure, necessitating anesthesia of only short duration. The operation usually gives good results even though probably no explanation for the retention is found. As a rule, the stomach is small, the stoma is of good size, and there is no evidence of obstruction. A gastrostomy may be performed on the stomach simultaneously. In this way all regurgitated gastric contents can be transferred to the tube in the jejunal stoma and the lost electrolytes can be replaced. A jejunostomy formula soon can be started and proteins may be easily given. In this way the surgeon has complete control of the situation and patients may do well for weeks with no oral feedings. It is important, finally, to stop the jejunostomy feedings and to allow the stomach to endeavor to empty itself. Continued jejunostomy feeding often will overload the jejunum and thwart normal gastric emptying.

Occasionally, an entero-anastomosis between the two jejunal limbs may be desirable. Often the patient is too ill or the performance of such a procedure simultaneously with the jejunostomy is technically impossible. If jejunostomy alone fails, an entero-anastomosis at a later date may be necessary.

Other procedures which have been recommended for correction of a malfunctioning stoma, but which have not been used extensively at the Mayo Clinic, are (1) second gastro-enterostomy, (2) duodenojejunostomy, (3) the insertion of the Abbott-Rawson tube at the primary operation and (4) the jejunoplasty procedure described by Hoag and Saunders.

RESULTS

The type of lesion encountered at operation may be an important factor in the development of both retention and subsequent gastrojejunal ulceration. About a fifth of the 200 patients were thought to have subacutely inflamed duodenal lesions (Table I). The remainder of the lesions were chronic or had caused accompanying pyloric obstruction.

Of the 100 patients in Group 1, 64 had no regurgitant vomiting. Twelve patients gave a history of gastro-intestinal hemorrhage. Active bleeding at operation was present in only one case, and that patient died three days post-operatively of hemorrhage. In the 35 cases of gastric retention in Group 1, the condition cleared after the usual treatment in less than five days in 11 cases. Retention occurred in only three women, and in two of these it cleared in less than five days. However, in 24 cases the regurgitant vomiting lasted five days or more, and in six cases some type of secondary operation finally was necessary. Gastric retention in all 35 cases developed from the sixth to the tenth day.

In six of the 35 cases, reoperation was required. One of these six patients (16.6 per cent) died. This percentage indicates that the risk is too great unless operation is absolutely necessary. In three of these six cases, jejunostomy was performed; all finally were cured of regurgitant vomiting. In one case an entero-anastomosis between the two jejunal limbs was performed. This patient recovered satisfactorily.

In the remaining two patients, entero-anastomosis and jejunostomy were performed simultaneously. One patient, previously mentioned, died of inanition and hemorrhage three days later, making a mortality rate of 1 per cent for the 200 cases.

Of the second 100 patients, 81 had no difficulty as far as regurgitant vomiting was concerned. Nineteen patients had gastric retention of some degree. Of the 19 patients, only two were women; in both cases the symptoms were mild. In 13 of the 19 cases the retention lasted for five days or longer, and in six cases it lasted only a day or so. There was no need for further operation in any of these 13 cases. Seven patients gave a history of gastro-intestinal hemorrhage.

The expense of hospitalization is a serious problem with most patients. Obviously, persistent gastric retention can be treated only in a hospital and adds greatly to that expense. The usual length of stay in the hospital for gastro-enterostomy is about 14 days. In Group 1 the 35 patients who had retention were forced to remain in the hospital an average of almost twice that length of time. Some of these patients were in the hospital more than 30 days. In four cases the patients were hospitalized for more than 50 days in all. One patient left the hospital only after 78 days. In Group 2 no patient remained in the hospital more than 23 days. In the 19 cases in which the patients had retention, an average of only four days more of hospitalization than the usual 14 was encountered.

SUMMARY AND CONCLUSIONS

A comparative study was made of two groups of consecutive cases of 100 each in which posterior gastro-enterostomy for duodenal ulcer was performed. The factors of age, sex, activity of lesion, position of stoma and technical skill were fairly constant. Because of the high incidence of postoperative retention in Group 1, changes in the technic of operation and of postoperative care were made in caring for the patients in Group 2 in order to combat postoperative gastrojejunitis, to promote peristalsis and to avoid overloading the stomach. These changes consisted of the use of three rows of sutures instead of two, as well as the postoperative regulation of fluid intake and the administration of medications, such as tablets of aluminum hydroxide gel (creamalin tablets), neostigmine (prostigmine methylsulfate), phenobarbital (luminal), atropine, diphenyl acetic acid and diethylaminoethanol (trasentin).

A comparison of the two groups revealed that the incidence of retention of any degree decreased from 35 per cent in Group 1 to 19 per cent in Group 2, and the incidence of serious retention (persisting longer than five days) from 24 to 13 per cent. In the first group six patients were subjected to secondary operation; in the second group there was no necessity for reoperation.

There is no single cause of postoperative gastric retention, so there can be no single remedy. The temperament, racial characteristics and emotional stability of the patient, as well as his economic and social stresses, are important. The size and position of the stoma, operative technic and preoperative and postoperative care are similarly important.

Regurgitant vomiting is of two general types: (1) The vomiting that develops immediately after operation suggests mechanical obstruction. (2) The vomiting that develops on the sixth to tenth day after operation occurs most probably because of stomal edema and inflammation. For the first type, some further operative procedure is frequently necessary; for the second type, supportive measures involving a knowledge of the principles of blood chemistry and fluid balance are usually sufficient.

Each surgeon should adopt an operative technic and a program of preoperative and postoperative care that embody those principles which in his hands give good results. In our experience, the stoma is best made on the posterior wall of the stomach with the proximal loop of the jejunum attached near the lesser curvature at the level of the angle of the stomach. The stoma is made to run diagonally downward and to the patient's left toward the greater curvature. Three rows of suture should be used in the anastomosis, the third solely to allow careful approximation of the mucosal edges and to cover all denuded portions. The distal loop should be carefully replaced in the abdominal cavity to lie behind all other loops of bowel. If secondary operation is considered, jejunostomy alone is the procedure of choice, and is usually all that is necessary.

REFERENCES

1 Allen, A. W., and Welch, C. E.: Jejunostomy for Relief of Malfunctioning Gastroenterostomy Stoma. Surgery, 9, 163–182, February, 1941.

2 Chauncey, L. R., and Gray, H. K.: The Relationship of Concentration of Proteins in the Serum to Postoperative Gastric Retention. Gastro-enterology, **1**, 72–94, January, 1943.

3 Eusterman, G. B., and Balfour, D. C.: The Stomach and Duodenum. Philadelphia, W. B. Saunders Company, 1935, p. 312.

4 Heublein, G. W., Thompson, W. D., Jr., and Scully, J. P.: The Effect of a Vitamin B Complex Deficiency on Gastric Emptying and Small Intestinal Motility. Am. J. Roentgenol., **46**, 866–875, December, 1941.

5 Hoag, C. L., and Saunders, J. B. deC. M.: Jejunoplasty for Obstruction following Gastro-enterostomy or Subtotal Gastric Resection. Surg., Gynec. & Obst., **68**, 703–712, March, 1939.

6 Lanman, T. H., and Ingalls, T. H.: Vitamin C Deficiency and Wound Healing: An Experimental and Clinical Study. ANNALS OF SURGERY, **105**, 616–625, April, 1937.

7 McCaughan, J. M., and Coughlin, W. T.: Posterior Gastrojejunostomy: An Unusual Error in Technique. Surg., Gynec. & Obst., **65**, 824–828, December, 1937.

8 Mayo, W. J.: The Technique of Gastrojejunostomy. ANNALS OF SURGERY, **43**, 537–542, April, 1906.

9 Ravdin, I. S.: Hypoproteinemia and its Relation to Surgical Problems. ANNALS OF SURGERY, **112**, 576–583, October, 1940.

10 Thompson, W. D., Ravdin, I. S., Rhoads, J. E., and Frank, I. L.: Use of Lyophile Plasma in Correction of Hypoproteinemia and Prevention of Wound Disruption. Arch. Surg., **36**, 509–518, March, 1938.

THE SO-CALLED "DUMPING SYNDROME" AFTER SUBTOTAL GASTRECTOMY

A CLINICAL STUDY

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SINCE THE MIDDLE 1930's and much before this, especially in Europe, radical resection of the stomach has become increasingly popular as a method of treatment for certain complicated types of benign peptic ulcer. Coincident with the increasing frequency of performance of partial gastrectomy, gastro-enterologists noted a corresponding increase in the number of patients who postoperatively exhibited vasomotor symptoms which comprise what is known as the "dumping syndrome."

HISTORICAL REFERENCES

The literature regarding this topic is not voluminous. Apparently the first article in the English medical literature to refer to the condition was written by Hertz[3] in 1913. Mix,[6] in 1922, described what he termed a "dumping stomach." This diagnosis was made on the basis of roentgenologic findings; the typical symptoms were absent. In 1935, Eusterman and Balfour,[1] in their textbook on gastro-enterology, recognized the occurrence of this syndrome after simple gastro-enterostomy as well as after gastric resection. They stated, however, that the condition was so rare after well-indicated and properly performed gastro-enterostomy as scarcely to deserve mention. They ascribed its occurrence to distention of the upper jejunum, a view with which we agree. Snell,[9] in 1937, likewise, referred to this disturbance but also regarded it as "fortunately a rare complication" which occurs after gastro-jejunostomy either with or without resection. "In a few cases," he said, "symptoms appear after meals, but once the jejunum becomes accustomed to the new hook-up these tend to disappear.

In 1940, Glaessner[2] cited nine cases in which he thought the typical symp-

* Abridgment of thesis submitted by Dr. Custer to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of M. S. in Medicine.

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toms of the postgastrectomy, or dumping syndrome, were attributable to "hyperglycemic shock" related to sudden increase in the concentration of blood sugar as a result of rapid resorption of sugar by the jejunum. In 1942, Schwartz, Reingold and Necheles,[7] however, were unable to correlate the level of blood sugar with the appearance of symptoms and favored distention of the upper part of the small bowel as the underlying factor. They suggested that the distress could be aborted or lessened by the use of frequent small meals and by lying down

Jordan,[4] in 1941, recognized the syndrome in a discussion of the end-results of radical surgical procedures for peptic ulcer. She said that in cases in which partial gastrectomy had been performed anastomotic ulcers and the dumping syndrome accounted for 25 per cent of cases in which unsatisfactory results were obtained. Mateer,[5] in discussing Jordan's article, placed the incidence at about 14 per cent.

SYMPTOMS

The symptoms have been considered by some observers to be the result of hyperexcitability of the parasympathetic nervous system, or a manifestation of vagotonia. Other observers apparently have been disinclined to recognize the syndrome and have regarded the alleged symptoms as nonexistent or of functional origin. Physicians who have observed substantial numbers of these patients, however, either during their immediate hospital convalescence or during later consultation, do not doubt the presence of symptoms or the fact that they comprise definite clinical, or at least symptomatic entity.

The distress usually begins within the first 10 to 14 days after operation. It may and, as a matter of fact, frequently does, date from the first postoperative meal in which solid foods are included. Occasionally the onset may be delayed three to four weeks after operation and rarely six weeks.

The similarity of symptoms in these cases is astonishing, and they vary only in severity. The distress is entirely painless but is, nonetheless, disabling. It is invariably related to eating, and an attack may occur after every meal or only after an occasional one. For some reason, as yet unexplained, breakfast most frequently causes discomfort and several of our patients have experienced difficulty only after this meal. The size and nature of the feeding do not appear to be important factors, although approximately 20 per cent of our patients have implicated high carbohydrate foods, particularly rich desserts, as the precipitating factors.

The symptoms usually begin suddenly, either during the meal or within ten minutes afterward. The four cardinal, and almost invariable, symptoms are (1) profound nausea and weakness; (2) a generalized and unpleasant sense of warmth throughout the body; (3) a cold diaphoresis of the face, particularly of the forehead; and (4) cardiac palpitation. In severe cases there may be hypermotility of the small bowel with excessive borborygmus ending in explosive diarrhea. In milder cases diarrhea and vomiting are rare.

The attack, which usually lasts from 10 to 60 minutes, frequently can be prevented or relieved if the patient assumes the supine position. This method of securing relief is familiar to patients, as evidenced by the fact that "lying down" was almost the routine answer on a questionnaire in which we inquired: "What affords you the most relief?" One patient, whose symptoms persist in particularly severe form eight years after operation, remarked that she was feeling somewhat better but; "Who wouldn't, spending two-thirds of one's time lying down?"

PURPOSE OF STUDY

Observation of six patients who had been hospitalized for study and treatment of the typical dumping syndrome convinced us that this syndrome, which occurs, unaccountably after subtotal gastrectomy in certain cases, is composed of a well-patterned and closely related group of symptoms. Therefore, in June, 1942, a combined clinical and statistical investigation of this syndrome was undertaken to obtain information concerning its cause, incidence, prognosis, prevention and treatment. The foregoing topics will be discussed in consecutive order.

CAUSE

The sweating and palpitation that develop during an attack led us to speculate concerning the possible relationship between these symptoms and those of primary shock. However, a survey of the data in Table I disproves any etiologic relationship. Although a moderate rise in pulse rate ordinarily accompanies an attack, there is no other evidence of vasomotor collapse. The systolic blood pressure actually rises when the symptoms begin.

Vagotonia has been propounded as a causative factor in the production of the dumping syndrome. For this reason atropine sulfate was administered intravenously in amounts of 1/150 gr. (0.00043 Gm.) to four patients. Two injections were given to each patient on different occasions in an attempt either to block the attack or ameliorate the symptoms. The only effect noted was the customary parching of the mouth. Insofar as could be determined, the attacks were unaltered in duration and intensity.

Distention of the gastric remnant next was considered as a possible precipitating factor. However, deliberate overdistention of the remaining stomach by means of a balloon that had been attached to a nasal tube and then had been passed into the stomach failed to reproduce symptoms in two patients who were suffering daily from the typical dumping syndrome.

At the present time we are inclined to believe that the tendency of the stomach after subtotal gastrectomy to empty itself quickly, from which the dumping syndrome derives its name, is the chief causative factor. Sudden distention of the upper portion of the small bowel appears to be a trigger mechanism that initiates a widespread enteric reflex. This is characterized by nausea and excessive peristaltic activity, as evidenced by borborygmus,

TABLE I

CLINICAL FINDINGS ASSOCIATED WITH DUMPING SYNDROME

	Pulse Rate, Per Minute	Blood Pressure, Mm. of Hg.
Before attack	72	110/60
During attack	80	100/55
Before attack	84	108/80
During attack	84	124/75
Before attack	76	105/75
During attack	80	115/80
Before attack	54	95/65
During attack	60	100/65
Before attack	80	125/80
During attack	84	140/76
Before attack	64	120/65
During attack	68	136/80
Before attack	72	105/65
During attack	80	118/70

TABLE II

DUMPING SYNDROME AFTER SUBTOTAL GASTRECTOMY IN SERIES I AND SERIES II

Classification According to Severity of Symptoms	Cases	Per Cent
Series I (500 cases):		
Group A (mild)	12	2.4
Group B (severe)	10	2.0
Group C (disabling)	6	1.2
Total	28	5.6
Series II (112 cases):		
Varying severity	14	12.5

TABLE III

RESULTS IN TWENTY-EIGHT CASES FIVE YEARS OR LONGER AFTER SUBTOTAL GASTRECTOMY (SERIES I)

Classification According to Severity of Original Symptoms	No Reply	Status of Symptoms			
		Relieved	Mild but Persistent	Severe	Disabling
Group A (mild)	2	3	4	3	0
Group B (severe)	1	0	6	3	0
Group C (disabling)	1	0	0	0	5

TABLE IV

RESULTS IN FOURTEEN CASES FOUR TO TWELVE MONTHS AFTER SUBTOTAL GASTRECTOMY (SERIES II)

Type of Operation	Symptoms Continued	Symptoms Disappeared
Pólya	7	2
Shoemaker (Billroth-I)	0	3
Hoffmeister (Pólya)	0	2

and in severe cases, by violent diarrhea. We believe, moreover, that the development of this abnormal reflex is directly related to the size and type of gastro-enteric anastomosis. The puzzling fact remains, however, that on fluoroscopic examination after a barium meal practically all stomachs resected by the Pólya method empty rapidly; that is, within 15 to 30 minutes, and yet only a fraction of patients experience this annoying distress.

INCIDENCE

Since the postgastrectomy syndrome appeared from our study to be an important complication, determination of its exact incidence seemed essential. Consequently, the records of 500 consecutive cases encountered at the Mayo Clinic in which subtotal gastrectomy had been performed for benign peptic ulcer between January 1, 1935, and August 1, 1938, were studied carefully. These 500 cases subsequently will be referred to as Series I. Cases in which the symptoms were nonspecific or consisted of only indefinite postprandial nausea or indigestion were discarded. Only those cases in which the patients complained of typical nausea, weakness, warmth, sweating and palpitation with relief from lying down were selected. There were 28 such cases (5.6 per cent of 500), and they were divided into three groups according to severity of symptoms (Table II).

Group A (12 cases) was composed of patients who experienced typical symptoms but the symptoms were not sufficiently severe to interfere with normal activity. Group B (10 cases) was composed of patients who were sufficiently handicapped by postprandial distress to interfere with the performance of their daily work. Group C (6 cases) was composed of patients who were not only unable to work but also suffered more from gastric distress than they had prior to operation.

For the purpose of comparison, a smaller series of 112 recent consecutive cases (Series II) also was studied (Table II). In these cases subtotal gastrectomy for peptic ulcer with complications or for gastric malignancy had been performed by one of us (J. M. W.).[10] Dumping symptoms of varying severity occurred in 14 cases (12.5 per cent of 112). The higher incidence of the dumping syndrome in Series II than in Series I is attributable to the fact that since the surgeon was particularly interested in this syndrome, and since these patients came under our direct supervision, certain symptoms were recognized which might otherwise have been overlooked. In some cases typical postoperative symptoms are relieved within a few weeks, and since they are not regarded as significant, they may not be recorded by the physician unless he is particularly interested in this syndrome.

PROGNOSIS

The obvious question after a definite and appreciable incidence of the dumping syndrome had been established was: "What happens to these patients and to their symptoms?" The general practice has been to reassure these

patients concerning their symptoms, with the comment that within a few weeks or months "as the bowel adjusts itself to the new opening" distress gradually and spontaneously would subside.

The inaccuracy of this prophecy in many cases was apparent from a review of the cases in Series I. In numerous instances correspondence concerning continued distress was carried on for as long as five to eight years after operation. Thirteen of the 28 patients had considered the disturbance of sufficient importance to warrant one or more return visits to the clinic for consultation.

Consequently, on May 8, 1944, a questionnaire regarding the progress of symptoms was addressed to the 28 patients. The replies were discouraging since only three of the 24 patients who sent a report had had relief of symptoms. In these three cases (Group A), the symptoms always had been mild; in two cases the symptoms cleared up spontaneously in two years and in the third they disappeared three years after operation. The remaining 21 patients continued to have symptoms and, in most instances, the nature and severity of the distress were unchanged (Table III). In all cases operation had been performed between five and eight years previously.

PREVENTION

In 27 of the 28 cases in Series I, gastro-intestinal continuity had been restored after subtotal gastrectomy by means of a posterior Pólya-type of anastomosis. In the remaining case, a von Haberer modification of the Billroth-I operation had been performed. In our opinion, this high incidence of dumping syndrome after the posterior Pólya-type of anastomosis does not, in itself, incriminate this operation. In recent years this technic has been preferred at the clinic over all others and was employed in approximately 90 per cent of the 500 resections in Series I.

Nevertheless, we have surmised for some time that if the symptoms that we have described result from rapid dumping of a large bolus of food into the unprepared jejunum or duodenum, then the development of these symptoms may be directly related to the size of the new stoma. In the Pólya operation the stump of the stomach is anastomosed to the bowel and the resulting stoma is the width between the two curvatures. If the dumping syndrome is related to the size of the stoma, then the obvious solution should be an operation that narrows the gastric stump and, thus, provides a smaller gastrojejunal opening. Numerous procedures have been devised to accomplish this purpose, among them the Hoffmeister modification of the Pólya operation and the Shoemaker modification of the Billroth-I technic.

Approximately 15 months prior to preparation of this report, further study of this premise was undertaken. At first the results of the Hoffmeister modification of the Pólya operation and the Shoemaker modification of the Billroth-I operation seemed disappointing since typical symptoms, although always in a mild form, developed while the patients were still in the hospital.

Before long, however, we became aware of the fact that the symptoms were not only mild but also were transient. The Hoffmeister and the Shoemaker modifications were performed in 28 and 37 cases, respectively, and in no case did the dumping syndrome last longer than three weeks. Thirty-two of these cases are included in Series II. Of the 14 cases in which the dumping syndrome developed, only seven patients reported persistent symptoms when questioned by letter on May 8, 1944; these seven patients all had undergone a posterior Pólya anastomosis (Table IV).

In order to illustrate the foregoing discussion, three cases are presented. In Cases 1 and 2 (Series II) a severe dumping syndrome had followed gastro-enterostomy. After the Hoffmeister modification of the Pólya operation was performed in Case 1 and the Shoemaker modification of the Billroth-I operation in Case 2, the results were good. These cases are in contrast to Case 3 (Series I) in which a posterior Pólya anastomosis was performed.

REPORT OF CASES

Case 1.—A farmer, age 53, described a typical dumping syndrome which had occurred while he was still in the hospital after simple gastro-enterostomy performed in May, 1940. The symptoms had necessitated bed rest for an hour after every meal for the next two years and two months, and then unaccountably had subsided promptly with reappearance of the old ulcer distress.

Fluoroscopic examination at the Clinic revealed an anastomotic ulcer. The medical consultant expressed the opinion that reoperation was indicated but advised against a Pólya anastomosis because of the history of a dumping syndrome.

On March 7, 1944, a large gastrojejunal ulcer and the distal three-fifths of the stomach were resected. Continuity was restored by means of an anterior Hoffmeister type of anastomosis. The stoma, which purposely was made small, measured barely 1.5 inches (3.81 cm.) in diameter. The patient made an uneventful recovery, without once experiencing symptoms of rapid emptying of the stomach.

Case 2.—A housewife, age 44, reported that she had undergone gastro-enterostomy for duodenal ulcer in September, 1942. A definite dumping syndrome developed within the first week and persisted until reëxploration was undertaken on March 4, 1944, because of jejunal ulceration. The stomach was disconnected from the intestine and the distal three-fifths of the stomach was resected. A Billroth-I anastomosis was effected, using the Shoemaker modification. On the thirteenth postoperative day mild dumping symptoms appeared and lasted several days. Improvement occurred after the administration of dilute hydrochloric acid. When the patient was dismissed on March 27, three weeks and two days after operation, she was entirely free from symptoms.

Case 3.—A man, age 20, related that he had undergone gastro-enterostomy in 1934. A dumping syndrome developed during the early postoperative period and persisted for the next two and one-half years. He came to the Clinic because of recurrence of pain which was found to be on the basis of marked gastrojejunitis. The medical consultant recommended that the stomach be disconnected from the intestine but advised against resection because of the dumping phenomenon. However, in view of the marked inflammatory reaction encountered in the stomach at operation, resection of the lower half of this organ seemed advisable and a posterior Pólya anastomosis was made. A severe type of dumping syndrome (Group C) promptly developed; this has practically incapacitated him from the standpoint of performing any work. Recently he has been undergoing syncope during some of the attacks.

TREATMENT

Treatment of the dumping syndrome is a difficult problem. Few, if any,

patients can be completely relieved. In perhaps half the cases substantial improvement occurs with reduction of the frequency as well as the severity of attacks. We use the following measures, either singly or in combination: 1. Patients are advised to lie down after meals. Breakfast in bed may be beneficial. 2. Ephedrine, 3/8 gr. (0.024 Gm.) with two or three soda crackers before meals can be used. 3. An ounce of cream or an ounce and a half of olive oil can be taken at the beginning of each meal. Fats, acids and alkalies tend to delay the emptying time of both resected and unresected stomachs. 4. Six small feedings daily instead of the customary three meals may be helpful. A dry diet which eliminates milk and milk products sometimes relieves distress. Sweets may cause distress. 5. Ten to 12 drops of dilute hydrochloric acid in a third of a glass of water may be sipped through a straw 30 minutes before meals.

Of these measures, the most encouraging results recently have occurred after the use of hydrochloric acid. We were led to try it after demonstration by Shay and Gershon-Cohen[8] that, whereas, the resected stomach usually emptied completely in 15 minutes, the addition of hydrochloric acid to a bariumized meal produced a 50 per cent gastric residue after 60 minutes.

Of the 28 cases of dumping stomach encountered in Series I, 18 had postoperative studies of gastric acidity. In two of these cases low values for free acid were present after the test meal; that is 16 and 18 units, respectively. In the remaining 16 cases there was no hydrochloric acid response to the test meal. Two of these patients also were tested with histamine and found to have an histamine anacidity. Other drugs that have proved ineffective include atropine, insulin, *alpha* hypophamine and stilbestrol.

SUMMARY AND CONCLUSIONS

The dumping syndrome is a definite clinical, and probably physiologic, entity that occurs after gastro-enterostomy, either with or without gastric resection. It follows gastric resection in 5 to 12 per cent of cases. Since it apparently results from rapid dumping of food from the stomach into the unprepared jejunum, it is well named. When rapid dumping once has become established, it is apt to be permanent, since it probably is related directly to the size of the anastomotic stoma.

The results of operations that narrow the opening of the gastric remnant have been uniformly good; however, our series is still too small to insist, categorically, that this solves the entire problem. Reoperation for the dumping syndrome has not been undertaken but this is a procedure to be considered in some of the severe cases. The administration of dilute hydrochloric acid is of value in some cases. We believe, however, that prevention of the disturbance will prove more effective than its treatment.

REFERENCES

[1] Eusterman, G. B., and Balfour, D. C.: The Stomach and Duodenum. Philadelphia, W. B. Saunders Company, 1935, 958 pp.

[2] Glaessner, C. L.: Hyperglycemic Shock. Rev. Gastro-enterol., 7, 528-533 (Nov.-Dec.) 1940.

[3] Hertz, A. F.: The Cause and Treatment of Certain Unfavorable After-effects of Gastro-enterostomy. ANNALS OF SURGERY, 58, 466-472, October, 1913.

[4] Jordan, S. M.: End-results of Radical Surgery of the Gastro-intestinal Tract; as Seen by the Gastroenterologist. J. A. M. A., 116, 586-590, February 15, 1941.

[5] Mateer, J. G.: Discussion. J. A. M. A., 116, 590, February 15, 1941.

[6] Mix, C. L.: "Dumping Stomach" Following Gastrojejunostomy. S. Clin. North America, No. 3, 617–622, June, 1922.

[7] Schwartz, A., Reingold, I., and Necheles, H.: Investigation of the Relationship between Blood Sugar and General Complaints Following Subtotal Gastric Resection. Am. J. Digest. Dis., 9, 151-154, May, 1942.

[8] Shay, Harry, and Gershon-Cohen, J.: Experimental Studies in Gastric Physiology in Man: The Mechanism of Gastric Evacuation after Partial Gastrectomy as Demonstrated Roentgenologically. Am. J. Digest. Dis., 2, 608-613, December, 1935.

[9] Snell, A. M.: Behavior of Stomach after Operation for Duodenal Ulcer. Am. J. Surg., 35, 45-55, January, 1937.

[10] Waugh, J. M.: Effect of Fat Introduced into the Jejunum by Fistula on Motility and Emptying Time of the Stomach. Arch. Surg., 33, 451–466, September, 1936.

POSTAPPENDICECTOMY INTERSTITIAL INGUINAL HERNIA

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FAILURE to recognize anatomic relationships at the primary operation is an important factor in the recurrence of inguinal herniation. From July 6, 1942 to February 8, 1945, 369 right inguinal herniae were repaired on the Surgical Service at Brooke General Hospital. Of these, eight, or 2.4%, presented an unusual surgical finding. In each of these cases successful repair depended on the recognition of the existing relationships at operation. One of them, Case 3, had previously been operated upon unsuccessfully, with a persistence of the original hernia.

In 1911, Hoguet[1] called attention to the frequent occurrence of right inguinal hernia following appendicectomy with drained wounds. Many of these had not only a right inguinal hernia but an associated postoperative hernia at the site of the appendicectomy scar. Hoguet, and Watson[2] attributed the occurrence of the hernia to a weakening of the abdominal wall following injury to the ilio-inguinal and ilio-hypogastric nerves.

All of the herniae to be presented were right-sided and followed appendicectomy (Fig. 1). The interval between the appendicectomy and the discovery of the hernia varied from four to 27 years. They were classified clinically by all examining surgeons as inguinal herniae. In each instance there was an easily reducible bulging mass at the external inguinal ring which descended on coughing or straining. An associated McBurney scar was always present.

At operation, the findings were at variance with the clinical diagnosis. The usual oblique hernia incision was made. The region of the McBurney scar was avoided because of the surrounding scar tissue. On dividing the fascial covering of the cord, fat, resembling omentum, was identified (Figs. 2 and 3). This was separated in each instance by sharp dissection from the vessels, the vas deferens and adjacent connective tissue. No peritoneal sac could be found. The omentum was traced to its point of origin, a peritoneal defect at the site of the original McBurney incision (Figs. 5 and 6). In order to properly expose this defect it was necessary to divide the internal oblique and transversus abdominis muscles (Fig. 4). After the omentum had been separated from the parietal peritoneum, the inguinal region was carefully explored from within the abdomen. With one exception no inguinal hernia was found. (In Case 6 an associated, indirect, inguinal hernia was discovered). Following the careful exploration of the inguinal region the peritoneal defect was closed with interrupted cotton sutures (Fig. 7). The transversus abdominis and internal oblique muscles were approximated with interrupted, stainless steel, wire sutures (Fig. 8). A modified Bassini type of repair was then employed in reconstructing the inguinal region.

In the postoperative period the patients were uniformly treated with bed rest for 14 days. After this they were allowed unrestricted ambulation.

The results were excellent in the five cases which could be followed. No recurrences were reported in a varying period of three months to three years interval since operation. All of them are engaged in active physical labor.

Particular attention is directed to this bizarre type of hernia for the following reasons: (1) The frequency of its occurrence. (2) It is a complication of poorly closed, drained, or secondarily infected appendicectomy wounds. (3) Lack of recognition of the type of hernia present accounted for a previous failure of repair in one of the cases. (4) To emphasize the necessity of opening the peritoneal cavity in each inguinal hernia and of exploring the inguinal region carefully.

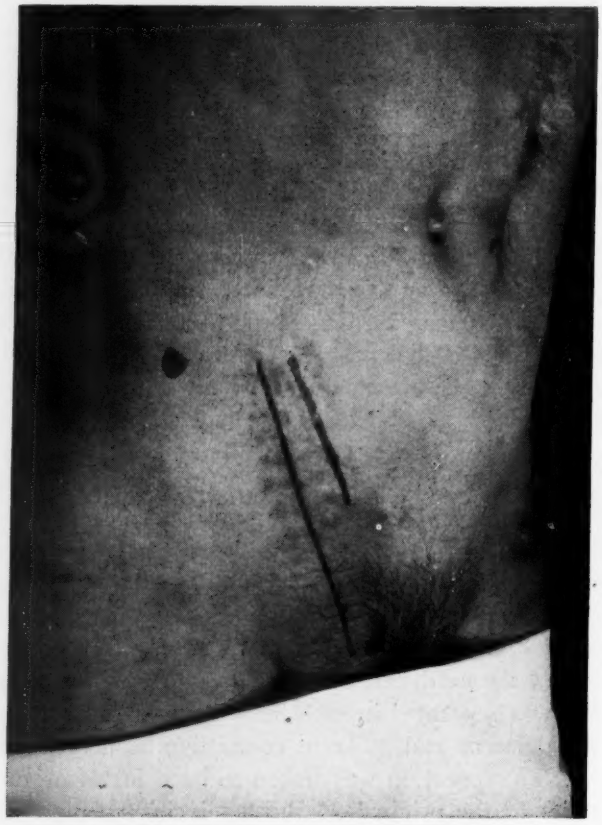

FIG. 1.—Photograph of the abdomen (Case 1), taken postoperatively, showing relationship of the McBurney scar to the incision for inguinal herniorrhaphy. The black dots are situated over the anterior superior spine of the ileum and the pubic tubercle.

Case 1.—A white male, age 51, was admitted to the hospital, February 18, 1945, with a diagnosis of right, indirect, inguinal hernia (Fig. 1). Previous surgery consisted of an appendicectomy in 1917 for a ruptured appendix and a resection of the transverse colon in 1938 for carcinoma. He had first noticed a swelling in the "right groin" one year prior to admission. This had been symptomatic for the past two months only. During

this period he complained of intermittent, sharp and aching pain on standing or walking for short distances. The swelling had grown larger during the previous few months.

Physical examination revealed a pendulous abdomen. There was no tenderness or palpable masses. A small ventral hernia was present at the site of the previous colostomy. No herniation could be demonstrated at the site of the old appendicectomy scar. There was an enlarged external inguinal ring on the right through which protruded a well-defined mass which increased in size on coughing or sneezing.

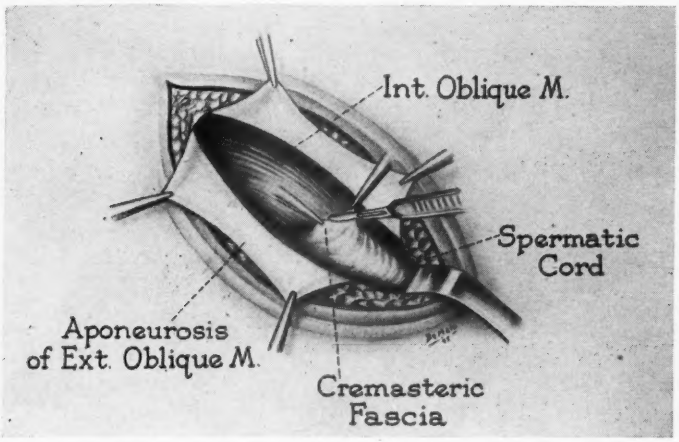

FIG. 2.—Diagram of the inguinal region before dividing the fascial covering of the spermatic cord.

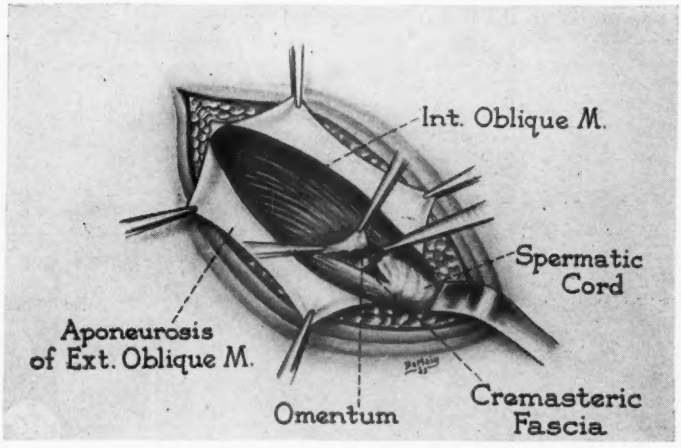

FIG. 3.—Diagram showing omentum within the cord. This is anchored above and extends below the opening to the region of the external inguinal ring.

At operation, February 24, 1945, the usual incision for the repair of a hernia was made. On incising the fascial coverings of the cord no peritoneal sac could be identified. Omentum adherent to the structures of the cord, however, was found to originate at a peritoneal defect of the old McBurney incision. The internal oblique muscle above the internal inguinal ring was divided to improve the exposure. Having dissected the omentum from the parietal peritoneum it was restored to its normal position within the abdomen. The entire inguinal region was explored from within the abdomen. No

hernial sac, either direct or indirect, could be demonstrated. The retracted peritoneal edges and transversalis fascia were mobilized and approximated with interrupted cotton sutures. The internal oblique muscle was sutured with interrupted wire sutures. A modified Bassini type of repair was employed in reconstructing the inguinal region. This man was discharged in excellent condition March 10, 1945. He is now employed, three months later, at farm labor.

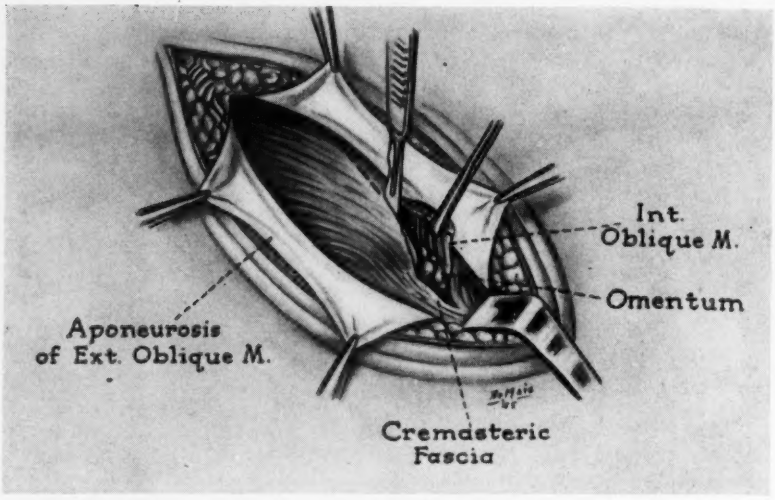

FIG. 4.—Diagram showing the internal oblique and transversus abdominis muscles divided. This improved the exposure of the peritoneal defect above and medial to the line of the inguinal incision.

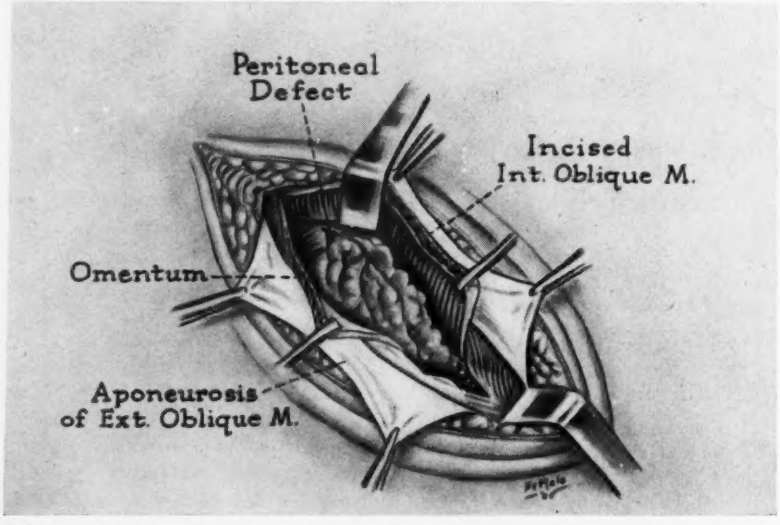

FIG. 5.—Diagram showing the omentum protruding through the peritoneal defect and extending down into the inguinal canal.

Case 2.—A 26-year-old white male was admitted to the hospital, February 17, 1942, with a diagnosis of a right, complete, indirect, reducible hernia. Previous surgery consisted of an appendicectomy in 1921. One day prior to admission to the hospital the

presence of a hernia was discovered on routine physical examination. He had had no previous symptoms.

On physical examination the abdomen was found to be soft and obese. An ancient, right McBurney scar was present, with no evidence of herniation. A small, right, complete, indirect, inguinal hernia could be felt.

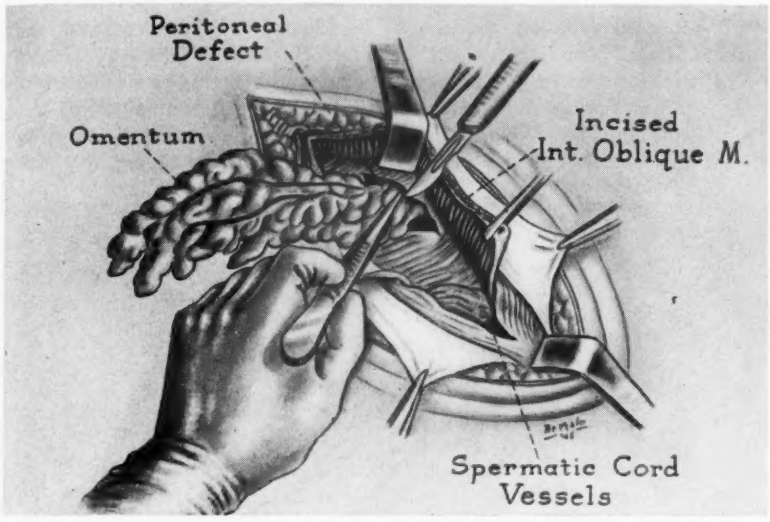

FIG. 6.—Diagram illustrating the dissection of the omentum from the parietal peritoneum in the region of the defect.

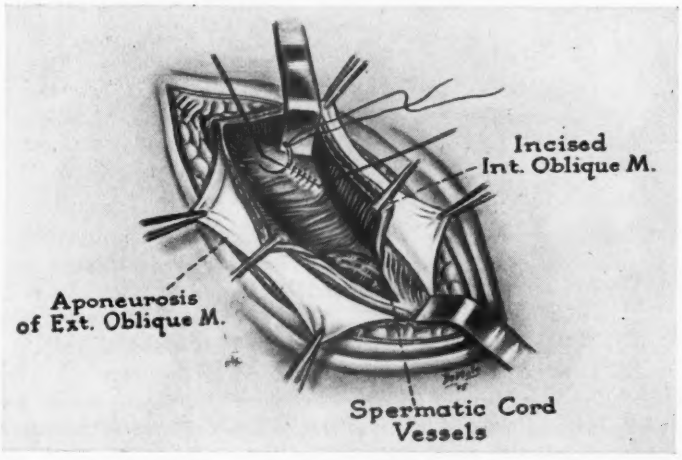

FIG. 7.—Diagram demonstrating closure of the peritoneum and transversalis fascia with interrupted cotton sutures.

At operation, February 19, 1942, the usual incision for an inguinal hernioplasty was made. On incising the fascial coverings of the cord no peritoneal sac could be identified. Omentum was found to be adherent to the cord structures. The origin of the omentum was a peritoneal defect at the site of the previous appendicectomy incision. The internal oblique muscle was incised in order to secure better exposure. The omentum was freed from the parietal peritoneum. The inguinal region was explored from within the abdomen and no hernia found. The peritoneal edges were approximated with interrupted

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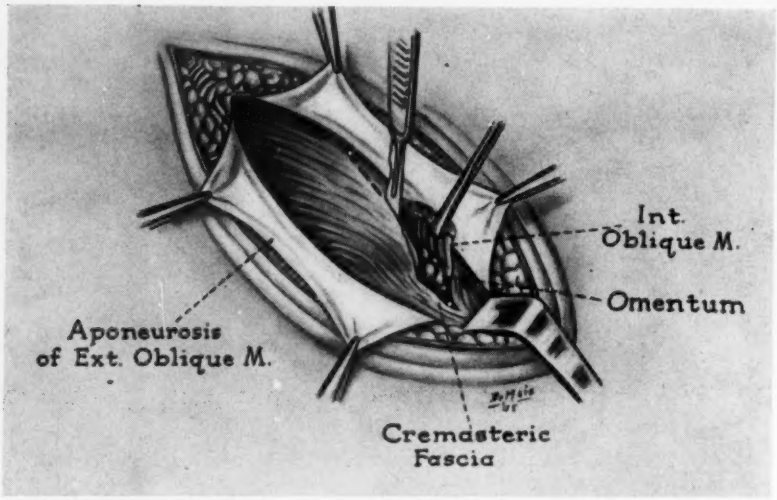

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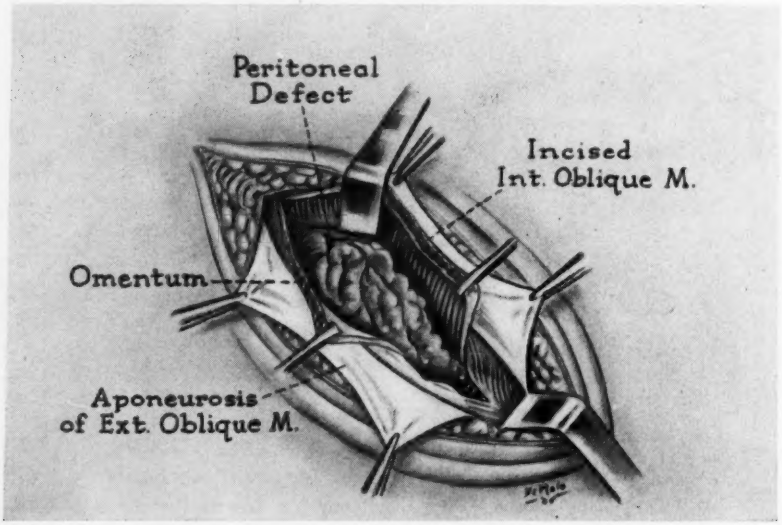

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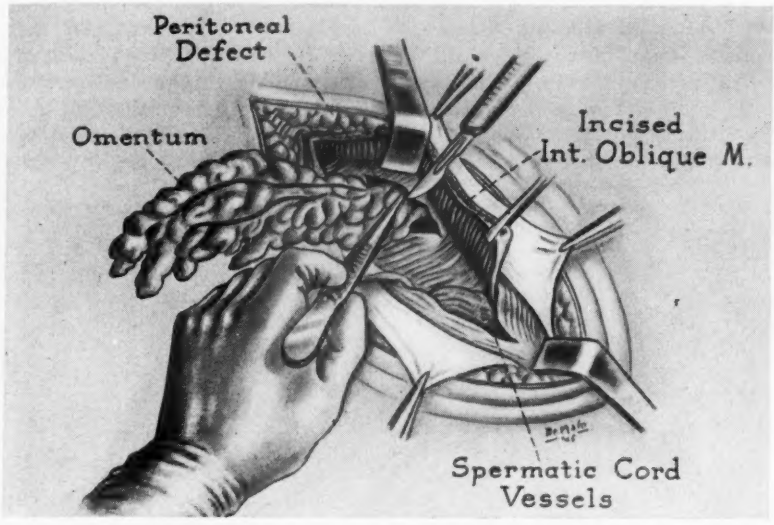
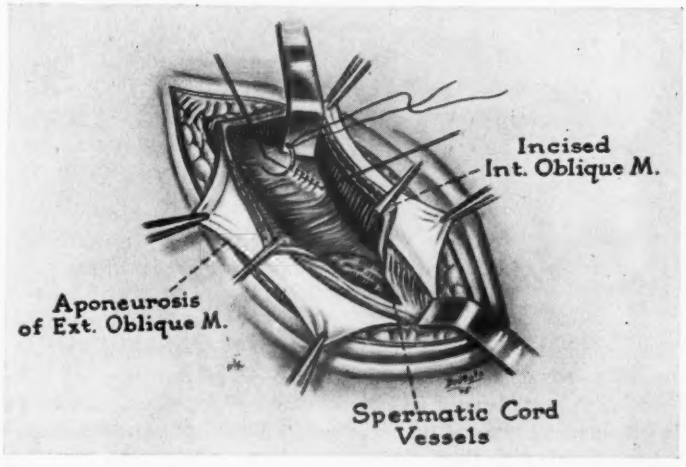


FIG. 6.—Diagram illustrating the dissection of the omentum from the parietal peritoneum in the region of the defect.



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cotton sutures. A modified Bassini operation was used in reconstructing the inguinal region.

The postoperative course was uneventful, and the man was allowed out of bed on the 14th postoperative day.

Since operation he has had no pain or discomfort. He has passed all of the physical examinations for Air Corps personnel overseas, where he is now assigned.

Case 3.—A white male, age 24, was admitted to the hospital, October 6, 1942, with a diagnosis of right, complete, indirect, recurrent, inguinal hernia. Previous surgery consisted of an appendicectomy (year unknown) and a right inguinal herniorrhaphy October 8, 1941. Following the previous repair of the right inguinal hernia he had no further symptoms until he developed a cough two months prior to his admission to the hospital. At this time he noted a recurrence of the herniation.

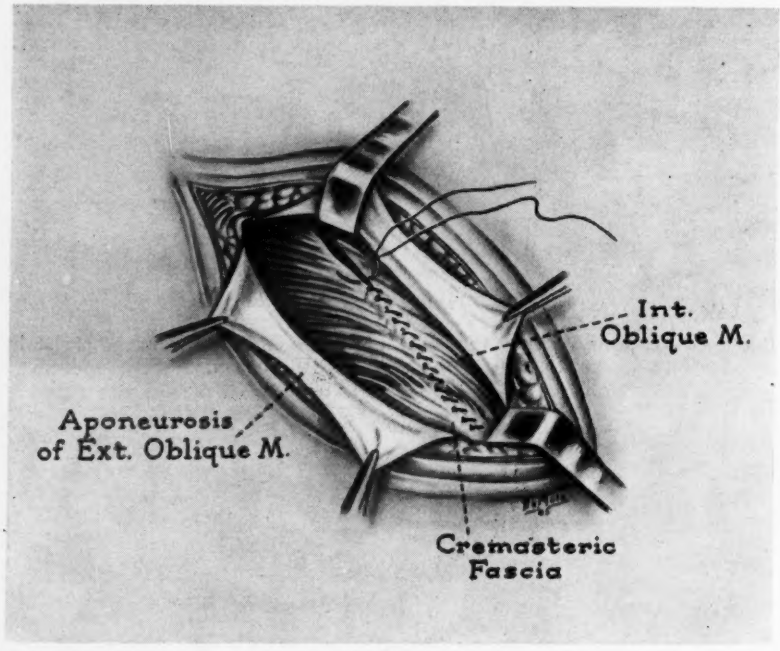

FIG. 8.—Diagram showing approximation of the divided edges of the internal oblique muscle.

On physical examination, an ancient herniorrhaphy scar was noted on the right side. Above and medial to the upper end of this was an old McBurney scar. There was no evidence of herniation at the site of the previous appendicectomy incision. There was a definite, reducible, inguinal mass in the right side, with an enlarged external ring.

At operation, October 8, 1942, the usual oblique incision was made excising the skin cicatrix. On incising the fascial layers of the cord, omentum was found to be adherent to the surrounding structures. The omentum was freed by sharp dissection and traced to a defect in the peritoneum up under the internal oblique and transversus abdominis muscles. These were divided to secure better exposure, and the peritoneal defect was found to exist at the site of the previous appendicectomy wound. The peritoneal cavity was explored in the inguinal region. No hernial sac, either direct or indirect, was found. The peritoneum and muscular layers were approximated separately. A modified Bassini procedure was used to strengthen the wall in the region of the internal inguinal ring.

The postoperative course was uneventful, and the man was discharged after a period of reconditioning on November 13, 1942. Since his operation this man has had no complaints and is now performing full duty with an Air Force Ground Crew overseas.

Case 4.—A white male, age 22, was admitted to the hospital, September 18, 1943, with a diagnosis of right, indirect, complete, reducible, inguinal hernia. He had had an appendicectomy in 1935. Six months prior to admission to the hospital, while lifting some heavy trays, the patient first noted pain in the right inguinal region. The pain was followed by a bulging or lump in the same area and the associated symptoms appear when he strains, lifts heavy objects or walks for a long period of time. Since appendicectomy in 1935 he has noted some pain at the site of the old McBurney incision.

Physical examination revealed a soft, well-healed, right, McBurney scar. There was a bulging in the region of the right, external, inguinal ring which expanded on coughing or straining. A diagnosis of right, indirect, inguinal hernia was made.

At operation, September 20, 1943, the spermatic cord was exposed through the usual inguinal incision. The fascial covering of the cord was divided. No peritoneal sac could be demonstrated but omentum was found to be adherent to the surrounding structures. The separated omentum was found to arise through a defect in the peritoneum at the site of the old McBurney incision. The internal oblique muscle was divided as in the other cases, the peritoneum closed, and a modified Bassini type of herniorrhaphy used in reconstructing the inguinal region.

After a period of reconditioning he was discharged from the hospital to full duty December 4, 1943. April 1, 1945 he was overseas in the combat zone engaged in the building of bridges. He has no complaints.

Case 5.—A white male, age 21, was admitted to the hospital, July 6, 1942, with a diagnosis of right, complete, indirect, inguinal hernia. Previous surgery consisted of an appendicectomy in 1935. The hernia was first noted on examination two weeks prior to hospitalization. This had been asymptomatic, and the man was not aware of its presence previously.

Physical examination: He was obese; the abdominal wall was thick and pendulous. There was no evidence of a herniation at the site of the previous appendicectomy. A right, indirect, reducible, inguinal hernia was present. This hernia extended down into the scrotum. All of the examining surgeons agreed that this was a perfectly typical inguinal hernia.

An operation was performed July 7, 1942. On incising the fascia of the cord, adherent omentum was encountered within. The source of the omentum was a defect in the peritoneum at the site of the previous appendicectomy incision. The internal oblique and transversus abdominis muscles were incised to secure better exposure. The omentum was dissected from the parietal peritoneum and the extraperitoneal portion excised. The inguinal region was explored for other herniations; none could be found. The peritoneal cavity was closed and the inguinal region reconstructed, using a modified Bassini procedure.

This man was discharged to full duty on August 12, 1942. He is still in the army, but we were unable to contact him concerning his present condition.

Case 6.—A white male, age 22, was admitted to Brooke General Hospital, August 12, 1944, with a diagnosis of right, inguinal hernia. He had had an appendicectomy in 1940. April 15, 1944, in Italy, while lifting some pipe, he noticed a sticking pain in the right inguinal region. Since that time a "knot" appears in that location if he lifts a heavy object or stands in one place for any period of time. There had also been a considerable amount of associated discomfort in this region.

Physical examination: There is an ancient oblique scar low in the right lower quadrant of the abdomen; no herniation is demonstrated at this site. A right, indirect, inguinal hernia was also present.

At operation, August 14, 1944, the usual hernia incision was employed. On opening the external oblique fascia, adhesions of this fascia to the internal oblique muscle and anterior sheath of the rectus muscle were encountered in the region of the old McBurney scar. This was located just above the inguinal incision. An indirect sac was found and opened. A defect in the peritoneum at the internal inguinal ring extended up into the abdomen. Through this defect omentum protruded extending down along the indirect hernial sac in an extraperitoneal location. The internal oblique muscle was incised to secure better exposure. The omentum was freed from surrounding structures. The peritoneal defect was closed above internal ring. A purse-string suture was then utilized to obliterate the indirect sac. A modified Bassini type of closure was employed in reconstructing the inguinal region. Following a period of rehabilitation this man was discharged from the hospital. He has had no complaints since operation. He was discharged from the Army for an unrelated condition and is now employed in farm labor.

Cases 7 and 8.—These clinical histories could not be obtained.

SUMMARY

A postoperative hernia arising in a McBurney incision is described. The hernia is characterized by a bulging at the external inguinal ring identical to that of a typical inguinal hernia. The fascia at the site of the McBurney scar is intact. The abdominal contents (in this series, omentum) courses through a defect in the peritoneum at the McBurney incision, finds its way under the transversus abdominis and internal oblique muscles to the inguinal canal. Transversing the inguinal canal, the omentum presents as a mass at the external inguinal ring, giving the impression of an inguinal hernia.

REFERENCES

1 Hoguet, Joseph P.: Right Inguinal Hernia Following Appendicectomy. ANNALS OF SURGERY, **54**, 673–676, December, 1941.

2 Watson, Leigh H.: Hernia. Second Edition, C. V. Mosby Company, 1938.

ANEURYSM OF HEPATIC ARTERY

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ANEURYSM OF THE HEPATIC ARTERY presents an unusual and exceedingly difficult diagnostic problem. The case herein reported, in which the diagnosis was established at operation and confirmed by autopsy after rupture of the aneurysm, is a typical and illustrative example. This aneurysm of the hepatic artery, and like the majority of such aneurysms, is considered to have been the sequela of an infectious process.

Case Report.—H. H. F., white, male, age 44, an insurance agent by occupation, was admitted to the hospital for diagnosis and treatment. The chief complaint was shortness of breath.

Family History: The patient's father, age 73, his mother, age 67, and two sisters and one brother were living and well. There was no history of the occurrence of mental disease, tuberculosis or cancer.

Past History: The patient had measles and mumps in childhood. He considered his health excellent at the time of enlistment in the army. He stated that while in the service he developed typhoid fever, complicated by influenza and pneumonia.

He was critically ill for a long time, and during convalescence was told that his heart was damaged—a leakage of the mitral valve. He received a discharge from the Service, November 28, 1917, because of cardiac disability.

In 1929, he was operated upon for ruptured appendix. There was no definite history of rheumatic fever, severe tonsillitis, diphtheria, scarlet fever or erysipelas. The patient denied any history of venereal disease. He denied the use of drugs. He used alcohol occasionally, and smoked moderately.

Present Illness: Following discharge from the army the patient had more or less difficulty with his heart, requiring rest periods at intervals.

For the past 15 years there had been shortness of breath on exertion, with a definite lessening of effort-tolerance during the past five years. During this time there had been evidence of pulmonary congestion, occasional palpitation and dull precardial pain. Blood-streaked sputum was noted on a number of occasions. However, there had been no occurrence of marked congestive failure.

Since the appendicectomy, in 1929, the patient had had periodic attacks of gas and distention, associated with marked constipation. Dull pain and tenderness were occasionally present in the right upper and lower quadrants of the abdomen.

The patient stated that six months before his present illness he had an attack of what he considered to be influenza, with a severe cough, prolonged fever, sore throat and marked prostration. He had remained in bed to the time of present admission to the hospital.

The temperature had been normal in the mornings, but rose to 103.6° F. in afternoons. There were no definite chills. During this time there was some abdominal distress, but nausea or vomiting were not experienced.

Two weeks prior to admission the patient noted red spots, which he thought were blood blisters, on his legs. These disappeared in about ten days, leaving a brown discoloration.

Physical Examination: The patient was a tall, slender, undernourished adult white male, well-orientated and coöperative. He showed a moderate pallor. He was lying in bed without respiratory distress.

Height was 72 inches; his weight was 156 pounds. Eyes and mouth were negative. The cervical veins of the neck were slightly distended. The lungs were negative. The peripheral vessels were soft and compressible. The apex impulse was diffuse and heaving. On percussion, the left border of the heart was 14 cm. from the midsternal line in the sixth interspace. The right border was percussed 4 cm. from the midsternal line in the third, fourth and fifth interspaces. The sounds were irregular in force, rate, and rhythm. The first mitral sound was accentuated, and booming in quality. There was a harsh crescendo presystolic rumble, which was followed by a high-pitched systolic murmur. There was a slight systolic murmur over the aortic valve. The pulmonic second was accentuated. Pulse rate 100. Blood pressure 100/90. There was slight tenderness in the lower right quadrant of the abdomen, beneath an appendicectomy scar. There was also slight tenderness over the liver area. The liver was palpable at the costal margin.

The spleen was not palpable and no masses were noted. The genitalia and rectum disclosed no abnormalities.

The skin showed no evidences of fresh petechiae, but there were a few scattered faint pigmented areas over the feet.

Neurologic examination disclosed nothing of interest.

Admission Diagnosis: (1) Rheumatic heart disease, with mitral stenosis; (2) cardiac enlargement, marked; and (3) auricular fibrillation.

Laboratory Data: The urine showed moderate albumin; few hyaline and granular casts, the specific gravity varied from 1005 to 1016; the P. S. P. 30; N. P. N. 30.4; the creatinin 1.6. The Wassermann reaction was negative.

The chest roentgenogram showed marked enlargement of the heart, with mild pulmonary congestion.

The electrocardiogram showed characteristic findings of auricular fibrillation.

Three blood counts were reported as negative. W. B. C. was 14,500, with 76 per cent polymorphonuclears. The R. B. C. was 5,300,000, hemoglobin 70 per cent; W. B. C. 14,000, 60 per cent polymorphonuclears.

Clinical Course: Following admission, the patient remained afebrile. He was put on a restricted diet, and was digitalized. He was ambulatory, without distress. Several days later he complained of severe pain in the epigastrium and upper quadrant. It had started with a dull ache the evening before, and continued through the night, becoming severe in the morning. Icterus of the sclerae was noted. Temperature was 101° F. The abdomen was extremely tender in the epigastrium and the right upper quadrant. There was definite localized rigidity in the right upper quadrant. At this time, the blood count showed W. B. C. 12,000, with 88 per cent polymorphonuclears. It was considered that the patient was suffering from an acute cholecystitis and cholelithiasis, with probable common duct stone. The patient stated that this distress was not unlike that which he had been suffering during the past few months, except that it was more severe.

The patient was treated conservatively. The pain continued, with frequent attacks of nausea and vomiting. Deep jaundice developed. A few days later a mass was felt below the liver edge, and was considered to be an enlarged gallbladder. Genito-urinary examination disclosed nothing significant. The Vandenberg test gave an immediate direct reaction. The total W. B. C. varied between 10,400 and 11,300. The polymorphonuclears varied from 80 to 88 per cent. An attempted biliary drainage gave no bile.

Operation.—Exploratory celiotomy: A slightly enlarged gallbladder was seen. The liver was moderately enlarged. A mass was seen posterior to the gallbladder and ducts, and extending posteriorly along the under surface of the liver. This mass was thickly covered with fibrin. Aspiration, with a small needle, showed arterial blood. The mass did not pulsate.

It was clear that the obstructive jaundice was due to compression of the ducts by this mass. Further operative procedure was considered inadvisable, due to the cardiac condition.

Postoperative Course: This was entirely satisfactory and uneventful until ten days later, when the patient suddenly complained of severe epigastric pain. He quickly went into shock, and died a few minutes later.

Autopsy: The subject was a fairly well-developed male, showing severe jaundice of the skin and sclerae. There was a recent right rectus surgical wound, and the abdomen was markedly distended. The abdominal cavity contained an enormous amount of dark red blood clot.

The mass which had previously been noted at operation was seen on the under side of the right lobe of the liver, just posterior to the gallbladder, and measured 8 cm. in diameter. It was somewhat fluctuant. A perforation was found in the posterior position of the mass which would admit the tip of the forefinger (Fig. 1).

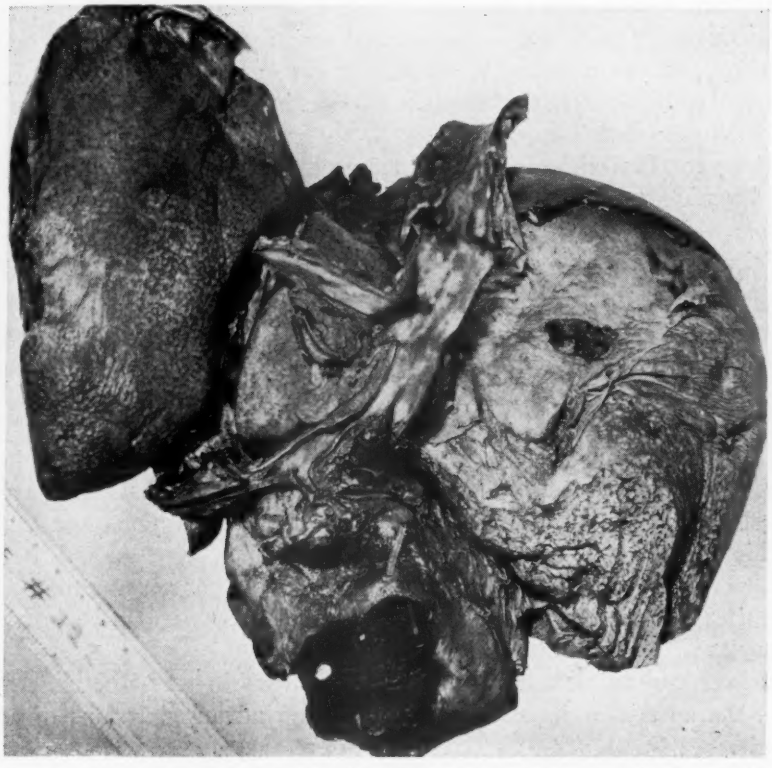

FIG. 1.—Under surface of liver showing ruptured aneurismal sac of the hepatic artery. The gallbladder has been dissected away.

On section, this mass was seen to be a large aneurysm, which contained laminated blood clot, causing the wall to be thickened to 2 cm. The center of the sac was filled with recent dark blood clot. Further examination showed that the mass was an aneurysm of the hepatic artery. Both the proximal and distal portions of the hepatic artery were identified.

Microscopic section showed that the wall of the aneurysm was composed of fibrous connective tissue, in which numerous small round cells were scattered. The inner surface showed organized blood clot. Section of the artery just proximal to the aneurysm showed no evidence of syphilis or arteriosclerosis.

The heart was enlarged, and weighed 500 Gm. There was dilatation of all chambers. There was marked hypertrophy of both ventricles. The right side of the heart was more dilated than the left. The mitral valve was thickened and fused, showing a typical

fish-mouth opening, 1 cm. long. Calcification was noted in the valve leaflets. The aorta showed a mild arteriosclerosis. The lungs and liver showed evidences of congestive heart failure.

Anatomic Diagnoses: (1) Aneurysm of the hepatic artery, ruptured, with massive hemorrhage into the peritoneal sac; (2) rheumatic heart disease, with mitral stenosis; (3) chronic passive congestion of the liver, lungs and spleen; and (4) jaundice.

Frequency and Occurrence: Rolland, in 1908, was able to collect 40 cases of aneurysm of the hepatic artery in the literature, and added one case.

Weiss, in 1921, was able to find 14 additional cases since Rolland's review, and added a case, making a total of 56 cases.

Friedenwald and Tannenbaum, in 1923, collected 65 cases of aneurysm of the hepatic artery from the literature, and described a case of their own.

Malloy and Jason, in 1942, reported a case of aneurysm of the hepatic artery, and collected from the literature 19 cases in addition to the series studied by Friedenwald and Tannenbaum.

Etiology: The etiologic factors concerned in the production of aneurysm of the hepatic artery are interesting because syphilis does not play the important rôle which it assumes in formation of aneurysms in general.

Weiss found that the majority of the recorded cases have followed acute infections, especially lobar pneumonia. In a series of 26 cases in which the etiology was determined with a fair degree of accuracy, 15 were associated with such conditions as pneumonia, osteomyelitis or typhoid; syphilis apparently was responsible for two cases; atheromatous aortitis, two cases; cholelithiasis, two cases; trauma, one case; and tuberculosis, one case.

Weiss noted that Schupfer reported a case of aneurysm of the hepatic artery following croupous pneumonia. He concluded that the aneurysm resulted from acute infectious arteritis produced by infectious agents transported in the vasa vasorum.

Grunert, according to Weiss, considered that 73 per cent of the 34 cases of aneurysm of the hepatic artery which he collected were to be interpreted as sequelae of infectious processes.

Aschner concluded that in his case the aneurysm was atherosclerotic in origin, the aorta and hepatic artery presenting advanced lesions of atherosclerosis.

In the series of 65 cases studied by Friedenwald and Tannenbaum definite causative factors were noted in 50 cases as follows: Generalized infection, seven cases; pneumonia, five cases; typhoid, two cases; pleurisy, with empyema, one case; osteomyelitis, three cases; arteriosclerosis, 12 cases; cholelithiasis, five cases; syphilis, seven cases; and trauma, eight cases.

Friedenwald and Tannenbaum say that trauma as an etiologic agent may act from without or from within, as by direct injury to the arterial wall by gallstones. They note that trauma was prominent in the case reported by Somner, in which the patient fell and injured the abdomen; Mester's patient was kicked in the abdomen by a horse; Brion's patient was subjected to frequent pressure on the abdomen with bars of iron during work.

Malloy and Jason found that infectious processes caused 41, or 60 per

cent of 68 cases of aneurysm of the hepatic artery, in which the cause was given. Next in frequency came arteriosclerosis (15 cases, or 22 per cent) and trauma (seven cases, or 10 per cent). Syphilis was not prominent in this series. Cholelithiasis was reported as the cause in five cases. Malloy and Jason think that the concomitant cholangitis is perhaps more important than the pressure caused by concretions. These authors add the thought that in cases wherein the lesion encroaches upon a passage of the digestive system, the intake of food and normal processes of digestion, may, as in this case, have been a factor in precipitating hemorrhage.

According to the study of Friedenwald and Tannenbaum, aneurysms of the hepatic artery are four times more common in males than in females. They found the age-range to be from 14 to 83 years, the average age in 63 cases being 38 years.

Malloy and Jason found a sex ratio of three males to one female in a series of 82 cases in which the sex was recorded (62 males, 20 females). They noted a wide age-distribution in this series, the youngest patient a ten-year-old boy, the oldest a man, age 83. The average age of occurrence was 38—for males 36, for females 42 years.

Pathology: Aneurysms of the hepatic artery have been divided into two groups: the extrahepatic and the intrahepatic. Friedenwald and Tannenbaum, in their study of 65 cases, found 45 extrahepatic and 18 intrahepatic, and two instances in which both intrahepatic and extrahepatic varieties were noted. In each of these two cases, the right branch of the hepatic artery presented an extrahepatic aneurysm while the left branch presented one of the intrahepatic variety. In 60 of this same series of 65 cases the main trunk was affected 29 times, the left branch six times, and the right branch 23 times, while in two instances the aneurysm was noted as a part of the cystic artery. In the case reported by Teacher and Jack, in a man, age 40, there was rupture of the left lobe of the liver caused by the bursting of an aneurysm of a small branch of the hepatic artery embedded deep in the liver tissue. The hepatic arteries were found to be the site of a widespread, patchy, subacute inflammatory condition. The cause of this condition was not clear, but the evidence was in favor of syphilis.

Malloy and Jason found in a series of 84 cases of aneurysm of the hepatic artery, in which the position is recorded, 61 were outside the liver, 20 were within the liver and three subjects had both intrahepatic and extrahepatic aneurysms. They add that while aneurysms of the hepatic artery are usually single in occurrence their series showed two aneurysms in six cases, three aneurysms in three cases, five aneurysms in one case, and "several" in one case.

Friedenwald and Tannenbaum, in their study of 65 cases, found that rupture of the aneurysmal sac occurred in 45 cases, while 13 remained unruptured. In 33 instances the rupture was into the abdominal cavity; in 21 the rupture was into the bile passages; in one, into the stomach; in two, into the duodenum; in one, into the portal vein. These authors note that in the case reported by Ledieu (1856), the ruptured aneurysm apparently underwent

spontaneous healing, being discovered in a patient who had died of renal disease. This aneurysm was occluded by a thrombus, and had produced no symptoms. In a similar case reported by Merkel, a thrombosed and calcified aneurysm of the hepatic artery, the size of an egg, was discovered incidentally at autopsy, and had produced no symptoms.

In the case reported by McCrae the aneurysm (2 x 3 cm.) was located at the bifurcation of the hepatic artery. In this case the thoracic aorta showed a dissecting aneurysm between the media and adventitia which extended for 16 cm. The inner surface of the aorta showed yellow nodular areas of degeneration suggestive of syphilis. In the left internal carotid there was a third aneurysm (7 x 4 cm.). The smaller arteries showed an extreme degree of obliterating endarteritis characteristic of syphilis.

Malloy and Jason say that the smaller aneurysms of the hepatic artery are usually true aneurysms resulting from dilatation of the vascular wall; the larger ones, however, are in part false aneurysms or hematomata resulting from rupture of the weakened vascular wall into the retroperitoneal tissues. Both true and false aneurysms become adhered to surrounding structures by dense fibrous adhesions and may cause compression of the bile ducts. Malloy and Jason add that eventually most of these aneurysms rupture either into the abdominal cavity or into some adjacent structure. Rupture occurred in 67 of the 85 cases they collected; 35 into the abdominal cavity; 22 into the extrahepatic bile ducts; seven into the duodenum; six into the gallbladder; one into the portal vein; one into the stomach.

Symptoms and Diagnosis: Teacher and Jack say that in some cases of aneurysm of the hepatic artery there have been no symptoms referable to the liver, the aneurysm proceeding to the rupture before its presence was suspected. Most authors agree, however, that in the majority of cases there are definite symptoms, the most common of which are pain, jaundice and hemorrhage (hematemesis and melena).

Malloy and Jason from their study of 85 collected cases found that aneurysms of the hepatic artery cause varied symptoms, but pain, hemorrhage, and jaundice occur with such frequency that they may be considered as aids in diagnosis. Pain (58 cases) was the most frequent symptom. It occurred in the right hypochondrium, the epigastrium or in both of these regions. Hemorrhage (40 cases) was next in the order of frequency, and occurred as profuse hematemesis or melena, or as occult blood in the stools. Repeated hemorrhage may cause severe secondary anemia. Jaundice (36 cases) was the third more constant symptom. It was usually of the obstructive type caused by compression of the common duct by the aneurysmal sac or rupture of the aneurysm into the duct causing obstruction by blood clot. The jaundice may be intermittent or persistent and severe.

According to Malloy and Jason less common symptoms are fever (noted especially in those cases associated with infectious processes) asthenia, headaches, constipation, and ascites. A pulsating tumor with systolic murmur and enlargement of the liver have been noted.

In Friedman's cases, paroxysms of pain were associated with a visible pulsation over the liver, accompanied by systolic shock felt over the ribs.

McCrae states that, in general, the striking clinical features of the reported cases of aneurysm of the hepatic artery have been pain, jaundice and hemorrhage into the digestive tract. The pain is paroxysmal, suggesting biliary colic. The hemorrhage is intermittent. Rupture into bile passages, stomach or duodenum is evidently present.

In cases which come to operation, diagnosis was not made after opening the abdomen in about half of the reported cases. McCrae says that in the majority of such cases, the condition has been diagnosed as ulcer or gallbladder disease.

Riml discusses the differential diagnosis of aneurysm of the hepatic artery. He notes that gallstone colic, bleeding duodenal ulcer, papillary carcinoma, and liver metastases must be considered. He says that a bleeding liver metastasis which causes colic is the hardest condition to differentiate prior to exploratory celiotomy. He describes a case in which the prominent symptoms of aneurysm of hepatic artery (gallstone colic and melena) were present, and observation of the clinical course led to a diagnosis (later verified) of mycotic aneurysm of the hepatic artery caused by sepsis lenta.

Treatment: Weiss concludes from his study of the literature that under favorable circumstances the treatment of aneurysm of the hepatic artery is ligation of the artery.

Ashner says where the diagnosis is made at operation ligation of the hepatic artery should be done. This author says that according to Langenbuch, Kehr, and others, when the pathology of the hepatic artery is such as to lead to a slowly progressive diminution of the blood which it supplies to the liver (as in the case of aneurysm), the formation of a collateral circulation takes place by way of the inferior phrenic. It is this fact which makes possible ligation of the hepatic artery (as successfully done by Kehr) without ill effects on the liver.

McCrae suggests ligation when operation is possible, but notes that there is always danger of hepatic necrosis. He mentions two successful cases in the literature (Kehr, Anderson). Anderson's patient was operated upon after rupture of an aneurysm of a branch of the hepatic artery. He had been operated upon for an aneurysm of the radial artery previously and was operated upon later for an aneurysm of the tibial artery. This patient improved under specific therapy.

Friedenwald and Tannenbaum note that since the first successful ligation of the hepatic artery for aneurysm was done by Kehr in 1903, nine other cases have been subjected to surgery (Riedel, Grunert, Merkel, Allessandri, Tuffier, Friedman, Baruch, Anderson and Kading). Of this series three patients recovered (those of Friedman, Anderson, Kading). Of 13 cases recorded in the literature which were subjected to operation in only eight cases was the correct diagnosis made at operation.

Gordon-Taylor presents a case which he says is unique, in that it is the only recorded instance in which anything except ligature of the parent artery

has been attempted as a surgical measure. He says that at operation a "considerable button" of aneurysmal wall was left on the artery and a reconstructive aneurysmorrhaphy was performed. The remains of the hepatic artery were sutured in layers. He says that subsequent bacteriologic findings in the blood clot of the aneurysm precluded any final success from aneurysmorrhaphy in this particular patient, but in order such aneurysms which have a noninfective cause this method can hardly yield results more disastrous than those attending ligation. He feels that the difficulties of aneurysmorrhaphy are by no means as great as those of ligation, and that the method is worthy of consideration when the surgeon at operation is confronted with an aneurysm of the hepatic artery.

Gordon-Taylor adds that the results of ligature of the main hepatic artery for aneurysm appear to be worse than those attending ligature of this artery under other circumstances. He finds that in a series of ten collected cases of ligature of the hepatic artery for conditions other than aneurysm the mortality rate was 60 per cent; in a series of 12 cases of arterial ligation for aneurysm of the hepatic artery or its branches 75 per cent of the patients succumbed. In this series Gordon-Taylor says that in two of the three surviving patients there was no certainty that an aneurysm was present. He believes that Kehr's case is the only positive success in ligature of the hepatic artery for aneurysm.

Malloy and Jason feel that treatment of aneurysm of the hepatic artery, like that of aneurysms in general, is unsatisfactory. Ligation is dangerous, likely to result in death from liver necrosis or insufficiency. They offer the hope, however, that if the diagnosis can be established, the surgical approach "perhaps by gradual reduction of blood supply to the part and establishment of a collateral circulation" might lead to a larger percentage of cures. At the present, they feel that the prognosis is decidedly unfavorable.

SUMMARY

A case of ruptured aneurysm of the hepatic artery, occurring in a patient with rheumatic heart disease, is reported. It is considered that this case was of infectious origin since no gross or microscopic evidence of syphilis or arteriosclerotic changes were noted. A brief summary of the relevant literature is included.

BIBLIOGRAPHY

Aschner, P. W.: A Case of Aneurysm of Hepatic Artery. Inter. Clinics, **2**, 234–238, 1923.

Friedenwald, Junius, and Tannenbaum, K. H.: Aneurysm of the Hepatic Artery. Am. J. M. Sc., **165**, 11–28, 1923.

Friedman, G. A.: A Tentative Diagnosis of Aneurysm of Hepatic Artery and Findings at Operation. Med. Rec., **82**, 522–524, 1912.

Gordon-Taylor, Gordon: A Rare Cause of Severe Gastro-intestinal Hemorrhage: With a Note on Aneurysm of the Hepatic Artery. Brit. M. J., 504,–505, April 24, 1943.

Sojecki, B.: Ein Fall von geplatztem Aneurysma der Leberarterie. Wurzburg, 1904.

Taylor, Erwin: Ruptured Aneurysm of the Hepatic Artery. New England M. J., **208**, 644, 1933.

Teacher and Jack: Glasgow M. J., page 277, 1916.

Weiss: Am. Jour. Med. Sc., **161**, 859, 1921.

Kehr, H.: Der Erste Fall von erfolgreicher Unterbindung der Arteria hepatica propria wegen Aneurysm. M. M. W., **43**, 1861, 1903.

Kuntscher, G.: Postoperative Aneurysms der Arteria hepatica. Zentralbl. f. Chir., **64**, 2694–2696, 1937.

Malloy, H. R., and Jason, R. S.: Aneurysm of Hepatic Artery. Am. J. Surg., **57**, 359–363, August, 1942.

McCrae: International Clinics, **3**, 1, 1920.

Riml, O.: Zur Unterscheidungs diagnose des Leberarterien aneurysmas. Med. Klinik, **30**, 974–975, July, 1935.

Rolland, William: Aneurysm of the Hepatic Artery. Glasgow M. J., **69**, 342–358, 1908.

REFLEX VASODILATATION IN TUBED PEDICLE SKIN GRAFTS

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TUBED PEDICLE SKIN GRAFTS, as well as other types of pedicled grafts, not infrequently give rise to concern over their blood supply. This may occur following the first stage, or after any subsequent shift, and in spite of following the rules of relation of length to width, time before shift, or size of new attachment. In an effort to improve early circulation, particularly where it appeared inadequate, use was made of reflex vasodilatation produced by immersing an hand and forearm, or leg and foot, in warm water. The following report is of an investigation undertaken in order to evaluate the effect on tubed pedicle skin grafts of such a procedure.

Learmonth[1], in discussing the use of reflex dilatation in surgery, suggested it had wider application than was generally known, and specifically mentioned the improving of blood supply to skin grafts. The method used was that of Gibbon and Landis[2], who were able to raise the temperature of the lower extremities by immersion of the forearms in hot water. A thermocouple was used to measure skin temperatures. Twenty-one studies were made on 14 patients.

Tubed pedicle skin grafts were labelled A, B, and C for the purposes of this investigation as follows: Type-A were those whose ends had never been detached (Fig. 1); type-B those having had one end transplanted (Fig. 2); and type-C those having had both ends transplanted (Fig. 3). Type-A had intact vessels and nerves entering at each end; type-B had intact vessels and nerves entering at one end only; and type-C had had vessels and nerves at each end divided to form, literally, denervated masses of tissues living parasite-like by means of a newly formed blood supply in a foreign site.

METHOD OF STUDY

Areas to be examined were exposed for half an hour prior to the test, the patient lying quietly in bed. Surface temperatures were taken at three body sites, and at three sites on the graft every ten minutes during this period. Studies were begun when the temperature became stabilized. Mouth temperatures were taken during the first few experiments but, as no deviations from normal were noted, the practice was discontinued.

Next, one forearm and hand (or leg and foot) was immersed in a bath containing water at a temperature ranging between 42 and 47 degrees centigrade. This was continued for one-half hour, the bath being kept at a constant temperature. Temperature readings were taken as during the preliminary phase.

During the third half hour the patient lay quietly in bed as during the preparatory phase. Skin temperatures were again taken at the usual intervals.

The results are shown graphically in Graphs 1 to 14(b).

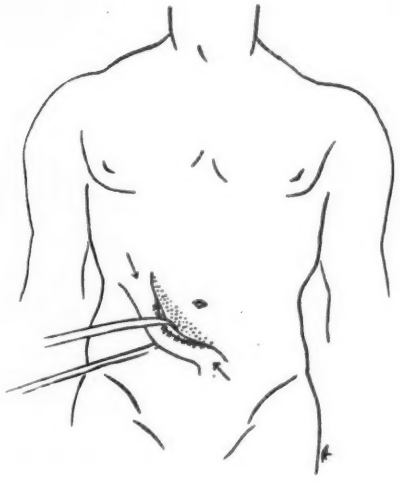


FIG. 1

FIG. 2

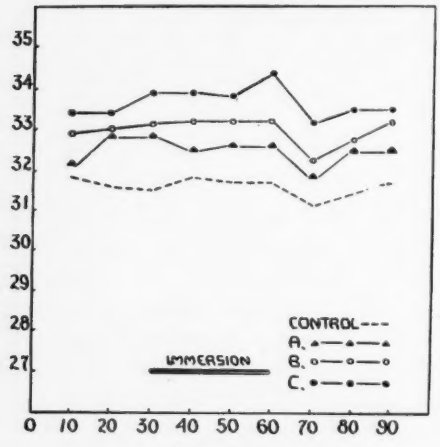
FIG. 3

FIG. 1.—Type-A Tube Graft: A tube of skin has been formed without interfering with the natural attachments at each end. The blood supply and nervous connections are uninterrupted.

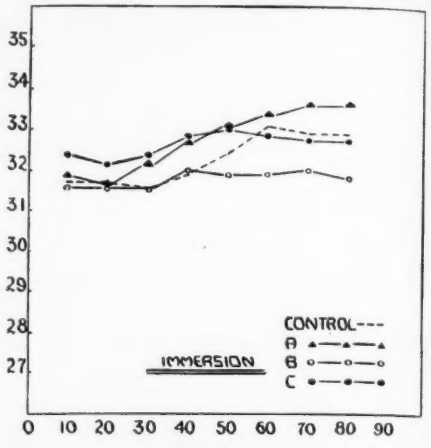
FIG. 2.—Type-B Tube Graft: One end of the type-A graft has been severed from its natural attachment and transplanted to a foster parent site. One natural attachment remains. One end is almost avascular immediately after operation, one set of nerves has been severed and one zone of inflammatory reaction and healing exists.

FIG. 3.—Type-C Tube Graft: The foster parent end having healed and vascularized sufficiently is able to take over the entire burden of supply and allow the natural end itself to be transplanted. These are denervated masses of tissue growing parasite-like through a newly formed blood supply in a foreign site.

SUMMARY OF RESULTS OF IMMERSION OF ONE LIMB SHOWN COMPARED TO ONE CONTROL AREA WITH SKIN TEMPERATURES IN DEGREES CENTIGRADE PLOTTED AGAINST TIME IN MINUTES. IMMERSION PERIOD IN EACH CASE LASTED FROM 30 MINUTES TO 60 MINUTES. (GRAPH 1—XIV)



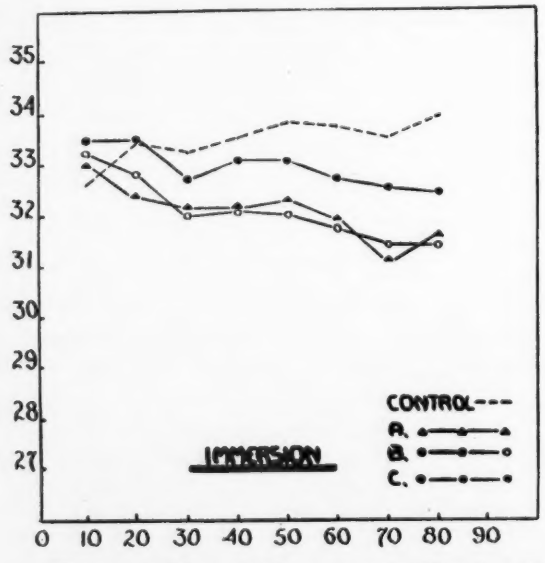
GRAPH 1



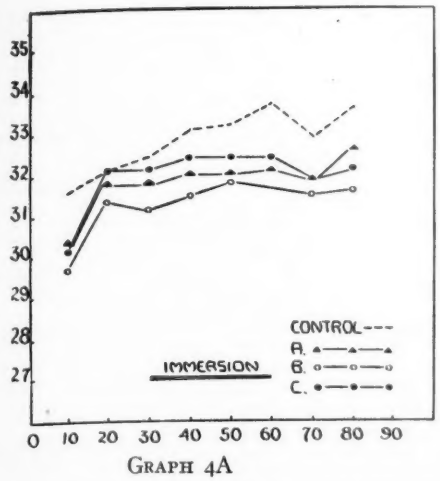
GRAPH 2

GRAPH 1.—A. E. B., a 28-year-old male, with 3.5-inch cervical tube (type-A) for reconstruction of ear—15 days postoperative. Tube appeared healthy, of good color but narrow and hard to study. Point C (lower end) apparently the main vascular supply showed only moderate response to peripheral dilatation. Sensation retained in tube. Control area—axilla.

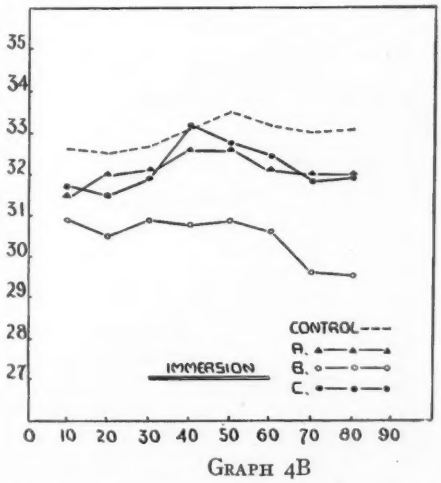
GRAPH 2.—J. F., a 23-year-old female, with 3.5-inch x 5/8-inch cervical tube (type-A) for reconstruction of ear. Tube formed 16 days previously, with intermediate bridge which was divided 12 hours before study. Tube healthy color but reduced sensation over middle portion. Point A (lower end) alone showed slight vasodilator response. Control area—cheek.



GRAPH 3.—Lieut. A. M., a 27-year-old male with five-inch abdominal tube (type-A) for grafting in defect of left hand—20 days postoperatively. Patient unusually sensitive to immersion bath. Has always sweated profusely—confirmed during examination. Patient remarked on feeling no body flush from immersion but felt pain at immersion site. Control area—cheek.



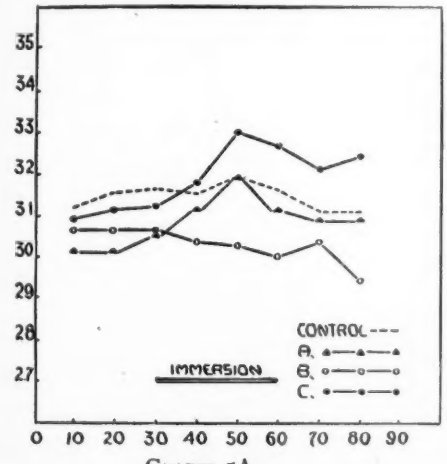
GRAPH 4A



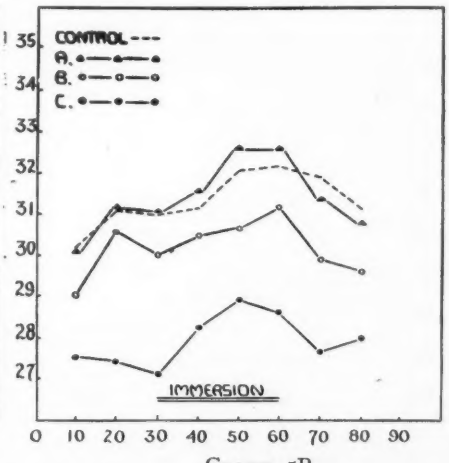
GRAPH 4B

GRAPH 4A.—Lieut. R. S., a 30-year-old male, with 4.5-inch abdominal tube (type A) for restoration of fleshy defect in hand—17 days postoperatively. Point C was lower end tube. Control area—cheek.

GRAPH 4B.—Lieut. R. S. (same patient as Graph 4), seen 12 hours after elongation of abdominal tube to nine inches (type-A). Point C again lower end (elongated end). Control area—cheek.



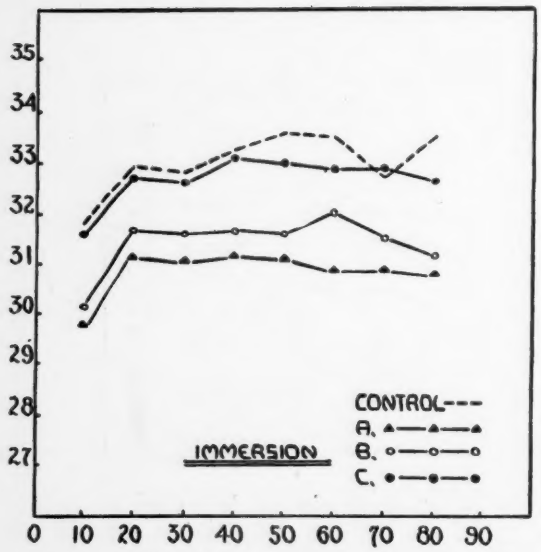
GRAPH 5A



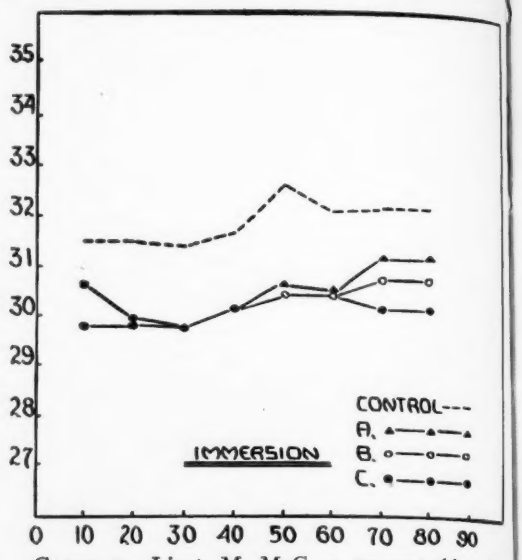
GRAPH 5B

GRAPH 5A.—A. G. H., a 26-year-old male with 9.5-inch abdominal tube (type-A) for restoration of popliteal defect, studied 22 days postoperatively. Tube of good color, warm, with rapid restoration of color after blanching under pressure. This tube had been lengthened in two stages to present length. Point C lower end tube. Control area—abdomen.

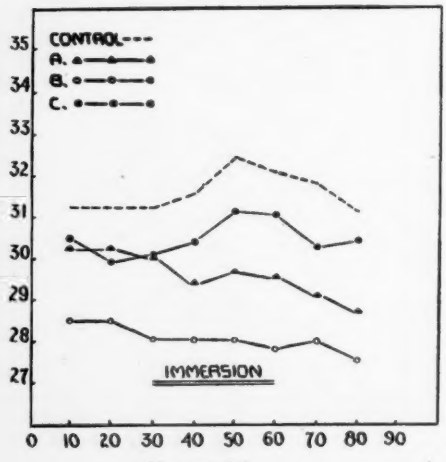
GRAPH 5B.—A. G. H. (same patient as Graph 5), examined 12 hours after upper end of tube had been transplanted to thigh. Point A on abdominal end. Point C on transplanted end in thigh. The lower half of the tube was bluish and cyanotic. During immersion this receded to the lower end and was barely visible at the conclusion. Type-B tube. Control area—cheek.



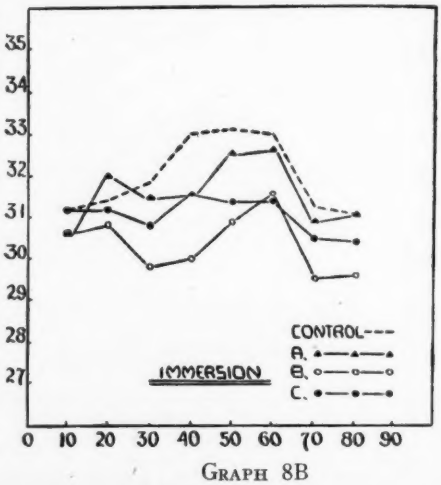
GRAPH 6.—M. G. R., a 22-year-old male, with nine-inch tube, originally formed on abdomen, now attached to right arm for final implantation on leg. Studied one week postoperatively. Type-B tube. Point C was abdominal end, Point A on arm end. Control area—cheek.



GRAPH 7.—Lieut. M. McC., a 32-year-old male, with pedicle flap from temporal region rotated to reform superciliary ridge overlying cancellous bone graft. Seen 12 hours postoperatively, graft of good color despite poor response to vasodilatation treatment. Four days afterwards flap turned cold, blue and precarious within 24 hours. Immersions continued and eventually entire graft survived without loss of tissues.



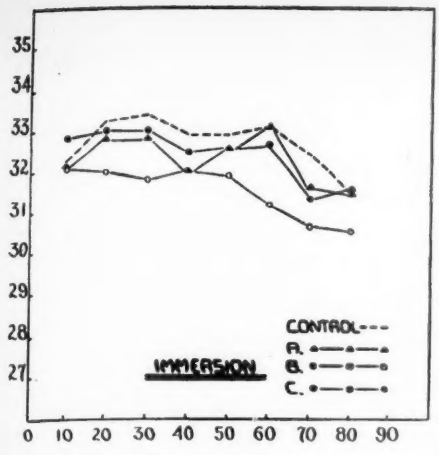
GRAPH 8A



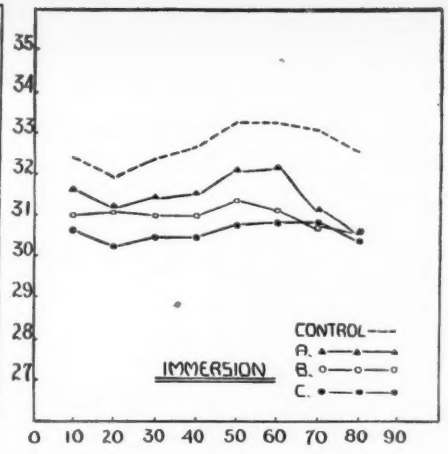
GRAPH 8B

GRAPH 8A.—K. A. H., a 21-year-old male, 8.5-inch abdominal tube formed to restore the defect in the leg, then attached to hand at one end, subsequently abdominal end attached to the thigh. Seen now in this stage (tube from hand to thigh, type-C), Point C was at the hand end of the graft. Despite poor response of central portion of tube, good color was maintained. Studied four weeks postoperatively. Note poor general reaction. Control area—cheek.

GRAPH 8B.—K. A. H. (same patient as Graph 8). Sixteen hours after the hand attachment severed and replaced in thigh. Color good, with good return of circulation after pressure. Point A was near first attachment to thigh compared with previous poor response. Tube type-C.



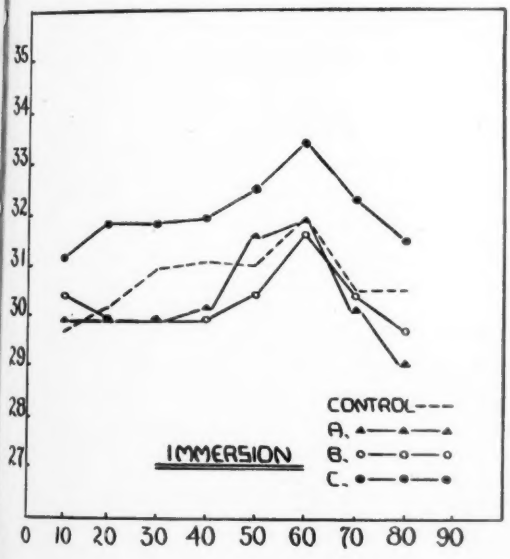
GRAPH 9A



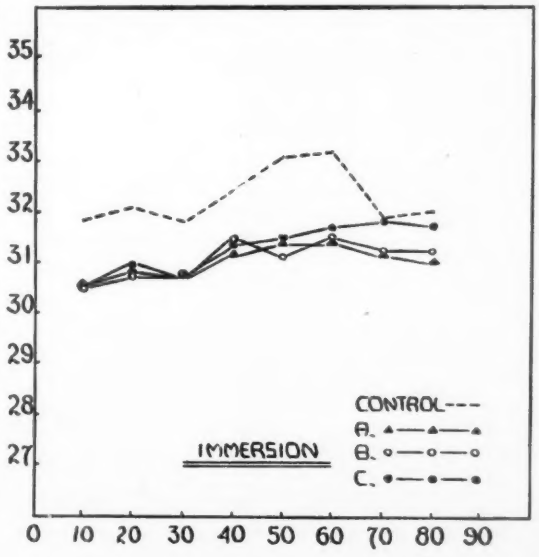
GRAPH 9B

GRAPH 9A.—Major D., a 45-year-old male. Had postradiation necrosis to thyroid cartilage and neck tissues. Ten-inch tube formed on back and slung over right shoulder so that one end of graft attached to anterior surface and the other end *in situ* on back (type-B tube). Case believed inadequately prepared before immersion—felt slightly chilly at end of preparation period. Note that temperature in tube maintained during immersion, but that other surface areas fell conspicuously in second resting period (postimmersion). Control area—cheek. Point A was taken on back near natural site of attachment.

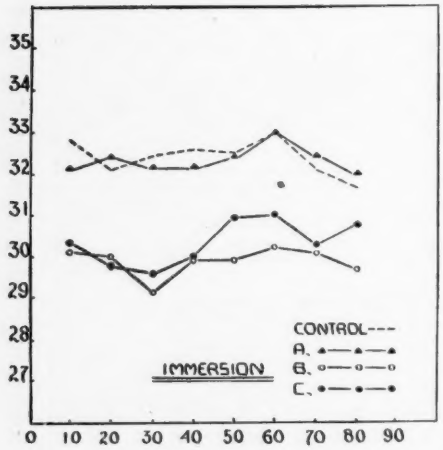
GRAPH 9B.—Major D. (same patient as Graph 9A). Twenty-four hours previously the back attachment of tube severed and slung into position in front of thyroid cartilage and sutured to provide a new anterior surface for the neck. The newly-sutured end became cyanotic and cool at once. Infrared radiation to abdomen added to immersion of foot giving a diffuse flush of the skin of the cheeks and neck, and the tube changed visibly with a pink flush beginning at the vascular end. Circulation obviously improved and more rapid return of color after gentle pressure (tube type-C). Point A—older attached end. Point C—newly attached end tube cyanotic. Control area—abdomen.



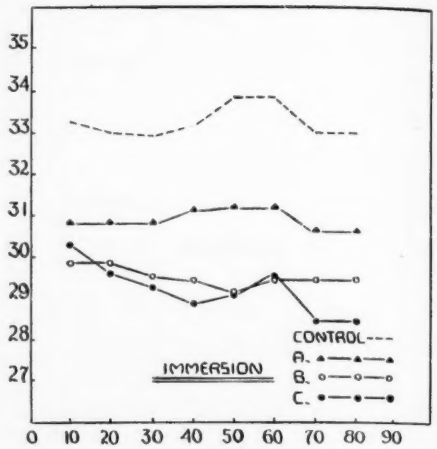
GRAPH 10.—B. G. A., a 26-year-old male with abdominal tube extending from the wrist to thigh (type-C tube), 28 days postoperatively. Good color and return of circulation after gentle pressure. Point C—older attached end. Control area—cheek. Excellent response to immersion. Notice lag in rise at Point B in center of tube.



GRAPH 11.—P. P., a 26-year-old male, seen eight days postoperatively, with type-C abdominal tube growing in forearm to reconstruct fleshy defect in upper limb. The abdominal attachment then severed eight days previously and Points A, B and C chosen so that A is at the older attachment, and B and C at more recent attachments, respectively. Control area—cheek.



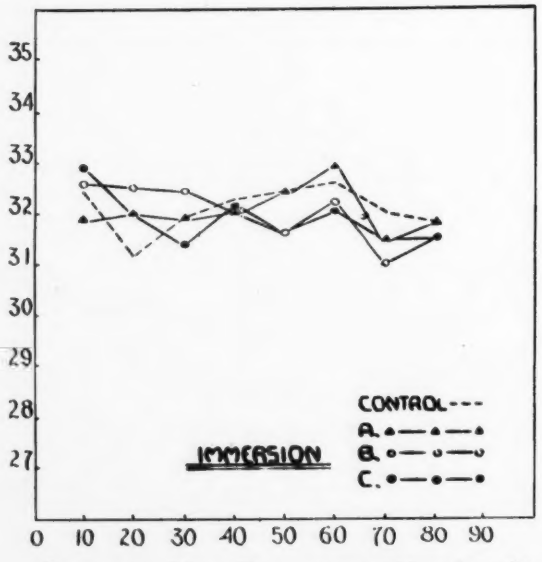
GRAPH 12A



GRAPH 12B

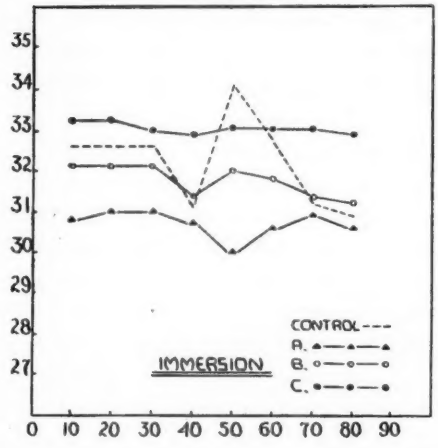
GRAPH 12A.—W. T., a 22-year-old male, with type-A nine-inch abdominal tube for reconstruction of hand—32 days postoperatively. Color, warmth and appearance excellent. Point C lower end of tube. Control area—cheek.

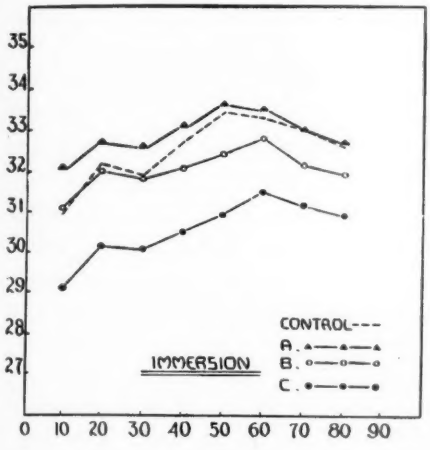
GRAPH 12B.—W. T. (same patient as Graph 12). Seen 12 hours after next stage at which the lower end of tube attached to hand (type-B tube). A attached at the upper end (abdominal tube). Note main vascular supply at abdominal end and rapid fall of Point C directly after immersion period. Control area—neck.



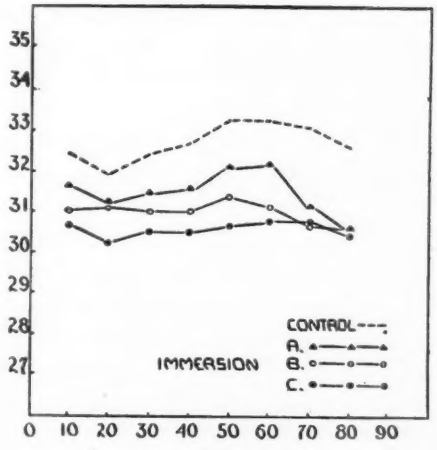
GRAPH 13.—Lieut. T., a 20-year-old male, with 12-inch abdominal tube without intermediate bridge. Type-A. Studied 19 days postoperatively. Region of Point B (center of tube) showed a 1-in. x 1-in. ulcer, with infection, and poor vascular return to gentle pressure. Point A lower end of tube. Control area—cheek.

GRAPH 14A





GRAPH 14B



GRAPH 14C

GRAPH 14A.—R. T., a 22-year-old male, with six-inch abdominal tube for reconstruction of nose. Tube now extending from right wrist to nasal site, 16 days postoperatively. Patient sat up for 15 minutes during immersion period, blanched, and began to perspire and felt dizzy. Temperatures all fell accordingly. Point A near wrist attachment, Point C near nasal attachment. Control area—axilla. Repeated a few days later (see Graph 14B).

GRAPH 14B.—R. T. (same patient as Graph 14) repeated, with patient remaining lying down. Control area—cheek.

GRAPH 14C.—R. T. (same patient as Graphs 14 and 14B) studied 12 hours after arm attachment severed, Point C taken on upper part of new nose, Point A at the lower end of nose (older attachment). Control area—chest.

The common known responses in peripheral circulation as described by Lewis[3], namely, the white reaction, the red reaction, the flare, and the wheal, illustrate that capillaries can react independently of nerve supply.

Gibbon and Landis[2] propounded two mechanisms to explain why warming one forearm produces vascular dilatation in the opposite hand. First, they state that sensory impulses from the heated limb, by reflex nervous mechanism, produce arteriolar dilatation in the opposite limb. Secondly, quot-

ing Pickering, they state that heated blood flowing centrally acts on a heat controlling center in the hypothalamus and through this reflexly brings about changes in the vasomotor tone. This center responds to phenomenally small variations, a change of 0.1 degree centigrade being sufficient to elicit a response.

Duthie and McKay[4] studied vasomotor reflexes in relationship to body temperature control. They investigated the phenomenon of widespread vasodilatation when heat was applied to one limb and concluded two mechanisms were responsible. One was a peripheral reflex vasodilatation from afferent impulses in the heated limb, the other the effect of heated blood on the thermosensitive center of the hypothalamus. They state: "Vasomotor reflexes from the skin may compensate for moderate variations in environmental temperature by increasing or decreasing heat elimination from the skin. Should these variations become more extreme a rise or fall in internal temperature will follow. The change in blood temperature by its action on the thermocenters in the hypothalamus leads to more vigorous conservation or elimination of heat."

Lewis and Grant[5] observed a flush in denervated digits following release of a pressure cuff which had been causing arterial occlusion. Goldblatt[6] studied hyperemic responses occurring independently of the nervous system. To eliminate sympathetic fibrils reaching the periphery along vessels he sectioned the latter and restored continuity by small glass tubes. He concluded that vasodilatation could occur independently of nervous connections. Doupe[7] concluded that reactive hyperemia is not dependent on any nervous mechanism and, in the denervated digit, is mediated in part by arteriovenous anastomosis.

In opposition to this, Lewis and Pickering[8] state: "While loss of sympathetic supply causes the corresponding fingers to be in general warmer than they otherwise would be, loss of all nerve supply causes the corresponding fingers to be in general colder than they otherwise would be, and, since with combined loss of motor and sympathetic supply the digits remain warm, it seems that the sensory nerve loss must be an important factor in determining the persistent coldness in cases of mixed nerve lesion."

It seems then that agreement has not been reached as to which of the various possible mechanisms produces vasodilatation in limbs remote from a source of heat. One thing appears certain, capillaries are capable of constriction or dilatation, on adequate stimulation, without involvement of any nervous mechanism. Landis[9] points out that local heat dilates capillaries. Thus, endothelial cells, although devoid of smooth muscle, can react to suitable stimulation by contraction or relaxation.

Arteriolar dilatation, in tissue still under nervous control, is the result of a much more powerful mechanism. However, one thing must be emphasized in discussing so-called denervated tissue—it is a serious error to describe an insensitive area as denervated when one tube attachment still remains. So far as the writers know the relationship between cutaneous nerve supply and autonomic supply still present has not been thoroughly studied. Do sympa-

thetic fibrils mediated by vessels supply the same territory as cutaneous nerves in the attachment, or have they wider ramifications?

Doupe and Cullen[10] report two cases indicating that, in denervated tissue as in normally innervated tissue, hyperemia follows injury.

We may conclude, therefore, that where nervous connections exist, strong vasodilator responses are possible but, on their absence, other mechanisms can account for some degree of vasodilatation. It would appear that capillaries and peripheral vessels can dilate or contract in direct response to minute temperature changes of blood. It is certain that denervated tissue responds rapidly to cold stimuli. Doupe[7] states: "The tendency to coldness of completely denervated digits is due to the hypersensitivity of the local vasoconstricting action to cold caused by the degeneration of the sympathetic fibers."

RESULTS

Before attempting to evaluate the results of this investigation certain points should be made:

(1) Temperature changes of less than 0.5 degree centigrade are not considered significant.

(2) Temperature maintenance during immersion, with subsequent fall in the later resting phase is as significant as an elevation.

(3) All tubes were protected from the underlying skin by dressing pads; thus, except for the attached ends, eliminating conducted heat.

Type-A Tube Grafts. The lower end of cervical tubes, fashioned for the repair of the helix of the ear, obviously carried the better blood supply; and, retaining diminished sensation, alone showed vasodilator response. The main response and higher temperature is at the lower end in abdominal tubes also. It would appear that, if an abdominal tube has to be lengthened at a second operation it should be done from the upper end.

Despite the fact that abdominal skin responds to a lesser extent to reflex dilatation than the skin of the neck or cheek the temperature in a type-A abdominal tube can be definitely raised, and presumably vascular channels dilated, by immersion of one limb in hot water. (See Graphs 3, 4, 5, 12 and 13.)

Type-B Tube Grafts.—Graphs 5a and b, 7, 9, 12a and b: It is hard to understand why there should be as good a response to vasodilatation over a newly attached end as over a natural attachment. It is believed that trauma liberates H-substance, shown by Lewis[3] to dilate arterioles. Possibly the absorption of this substance explains the hyperemia, and the rise in temperature is due to heat by conduction from inflammation.

Case 12(a) did not show any reaction to immersion; no appreciable response on any control site, and no response on the tube.

Type-C Tube Grafts.—Graphs 8a and b, 9a and b, 11, 14a and b: These denervated tissues showed less response in their central portions than in other types, and the older attached end invariably showed a greater rise in temperature than the newer attachment. Some of these type-C tubes showed a rise

of 1.7 to 2.0 degrees centigrade. This increase in surface temperature proves a material increase in blood supply.

The response of these grafts to cold is marked. The sudden drop after the immersed limb is removed from the heat bath may be due to the cessation of heat supply, a reaction similar in nature to the cold sensitivity described by Doupe[12]. These falls in temperature are present in almost every experiment.

One case[6], subsequent to implantation of his tube into the thigh made good progress for two weeks. His type-C tube was of good color, warm, and appeared healthy. One night this insensitive tube was exposed, by error, to a cool breeze from an open window for some time. When noticed, it had turned cold and cyanotic. Massage and immersion saved it although its color remained dark for several days. We believe that this was just such a reaction to cold as described by Doupe[7].

SUMMARY

Reflex dilatation as a means of increasing blood supply to tubed pedicle skin grafts has been studied in 14 patients. Appreciable rises in temperature were obtained in all but two cases when a limb was immersed in hot water.

Vasodilatation is not dependent on an intact nerve supply, although greater responses are seen when nerve supply is present.

Tubes show a marked sensitivity to the withdrawal of heat, a point to be borne in mind in the after-care of tubed pedicle skin grafts with precarious circulation.

It would appear that abdominal tubes are better lengthened from the upper end.

REFERENCES

1 Learmonth, J. R.: Reflex Vasodilatation in Surgery. Edinburgh Med. J., **50**, 140, 1943.

2 Gibbon, J. H., and Lendis, E. M.: Vasodilatation in the Lower Extremities in Response to Immersing the Forearms in Warm Water. J. Clin. Invest., **11**, 1019, 1932.

3 Lewis, T.: Blood Vessels of the Human Skin and Their Responses. Shaw and Sons, Ltd., 1927.

4 Best, C. H., and Taylor, N. B.: Physiological Basis of Medical Practice. 2nd Edition. Williams and Wilkins, p. 439, 1939.

5 Lewis, T., and Grant, R. T.: Vascular Reactions of the Skin to Injury.. Heart, **11**, 209, 1924.

6 Goldblatt, H.: Observations upon Reactive Hyperaemia. Heart, **12**, 281, 1926.

7 Doupe, J.: Studies in Denervation: Mechanism of Axonal Vasodilatation. J. Neurol. and Psychiat., **6**, 115, 1943.

8 Lewis, T., and Pickering, G. W.: Circulatory Changes in the Fingers in some Diseases of the Nervous System: With Special Reference to the Digital Atrophy of Peripheral Nerve Lesions. Clinical Science, **2**, 149, 1936.

9 Landis, E. M.: Capillary Pressure and Capillary Permeability. Physiological Reviews, **14**, 404, 1934.

10 Doupe, J., and Cullen, C. H.: Studies in Denervation; Inflammation and Trophic Ulcers in Denervated Areas. J. Neurol. and Psychiat., **6**, 112, 1943.

11 Duthie and MacKay: Vasomotor Reflexes in the Control of Body Temperature in Man. Brain, **63**, 295, 1940.

12 Doupe, J.: Studies in Denervation: Circulation in Denervated Digits. J. Neurol. and Psychiat., **6**, 97, 1943.

RHABDOMYOSARCOMA OF THE SKELETAL MUSCLES

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IN 1854, over 90 years ago, Weber described a localized enlargement of the tongue of a 21-year-old man. This was excised but later reappeared. It was made up of striated muscle cells in all stages of differentiation from adult to embryonal forms. Although this is not called a neoplasm by Weber there can be little doubt that it was a rhabdomyosarcoma. During the intervening years there have been published many studies of striated muscle tumors. One can learn from them that these are tumors of very variable gross characteristics, rate of growth and appearance, that they affect both sexes, all ages from the newborn infant to the octogenarian, that they grow at enormously variable rates of speed and develop in animals as well as man [rats and mice (Haagensen and Krehbiel; Morpurgo; Nettleship); fish (Kolmer); birds (Peyron); cow (Prochazka)]. They have been found in certain definite systems and regions of the body. These are more particularly the genito-urinary system (bladder, kidney, prostate, testis, spermatic cord, uterus, vagina, round ligament and ovary), the heart, upper respiratory and alimentary tracts, the orbit, and sporadic examples have been found in the lung, breast, esophagus, suprarenal and brain. In addition, the writer has been able to locate reports of 107 cases which have developed in the striated muscles and other soft parts of the body. From the clinical point of view this is the more interesting group because many of them develop in situations where they can be subjected to attempts at curative therapy. Therefore, it is of very considerable importance to learn the biologic characteristics as well as the gross and microscopic features of these tumors so that they may be recognized as early as possible and the best form of treatment employed. When the writer undertook to learn what he could from published work, he found that there have appeared a number of magnificently illustrated studies of the neoplastic myoblast by Glasunow, Montpellier, Peyron, Roskin, Temofeevskiy and Wolbach which make it relatively easy for those who use good technical practices to recognize the growth microscopically provided the tumor demonstrates some evidence of differentiation. But when one tries to find out about the biologic habit of the tumor and especially about the efficacy of treatment, the astonishing fact emerges that apparently no statistical investigation has been published—at least in the more easily accessible journals. Bick, Burke, Landois and Lenormant have each produced studies of tumors arising in voluntary muscles but without any attempt to distinguish between the various histologic types. Geschickter, Gordon Taylor, Moulonguet and Pollosson, and Rakov have studied groups of rhabdomyosarcomas but without furnishing enough details to enable one to make much use of them for statistical purposes. Shanin's paper

is in Russian, and the English abstract lacks essential details. De and Tribendi give valuable details of 13 cases and Jőnsson has produced a splendid monograph in English from the material of the Radiumhemmet, in Stockholm, with the necessary clinical data of 39 cases of rhabdomyosarcoma of the peripheral voluntary muscles, each one of which was diagnosed by Reuterwall. All of the writers mentioned have realized the extremely malignant nature of the rhabdomyosarcoma but not even Jőnsson, who had the information at his disposal, studied it statistically and made use of it to emphasize his conclusions.

The writer has, therefore, tabulated the published cases and added 14 unpublished ones at his disposal, making a total of 121 cases for analysis. Before this analysis is presented, it seems necessary to discuss the histology, classification and nomenclature of these tumors so that it may be perfectly clear what is meant by the name used and what tumors are included.

In this paper the intention has been to present the tumors that are definitely made up of cells which, in whole or in part, have some of the characteristics of rhabdomyoblasts and which have arisen in the striated muscles (exclusive of heart muscle) or immediately adjacent to them. The rhabdomyoblastic tumor cell is very variable in size but in general it is rather large and it assumes one of three different shapes. It is either rounded, strap-shaped with two or more nuclei arranged in tandem, or racquet-shaped with a single nucleus at one expanded, rounded end, and a tapering body extending outward from this for a variable distance. The cytoplasm is generally somewhat acidophilic, and sometimes markedly so. It is often granular. If the tumor material is well-fixed and stained with either Masson's trichrome stain containing acid fuchsin, Haidenhain's hematoxylin or (if Zenker fixation is used) with the phosphotungstic acid-hematoxylin stain, either cross-striations, longitudinal myofibrils or some vague suggestion of their formation should be distinguishable in the majority of cases. It is usually not easy to find this differentiation even with very good preparations and one must be willing to make a painstaking search with high magnification. But the search is rewarding if successful, for the diagnosis can then be made with complete assurance. One or the other of these differentiating features was found in nine of the 14 new cases here recorded. In embryonic myoblasts or myoblasts from adult striated muscle *in vitro* (Pogogeff and Murray), the formation of cross-striations and longitudinal myofibrils is markedly variable; they appear, disappear and reappear within a cell sometimes rapidly and sometimes after long intervals. Moreover, the cross-striations often do not completely traverse the elongated strap-like cells. Reproduction of these vagaries is found in tumor myoblasts (Figs. 5, 7, 10 and 11). The tumor cells are sometimes vacuolated and it has been generally accepted that the material in the vacuoles is glycogen, since Marchand demonstrated this in 1885. Glycogen determinations have not been done in any of the new cases reported here. When there are many vacuoles in cells of giant size, they are sometimes peripherally arranged with delicate cytoplasmic strands separating them and radiating outward from near the nucleus to the capsule. Such cells have been called spider or spider-web

cells. But even if one is unable to demonstrate cross-striations and fibers the other histologic features will usually suffice to make the diagnosis. Jőnsson reported that he did not find them in a single one of his 39 cases of rhabdomyosarcoma. The photomicrographs, however, are sufficient to enable one to accept his cases as authentic, especially when one is assured that they were all studied by Olle Reuterwall. It should be noted that the rhabdomyosarcomas may not show these characteristics in all parts. One may encounter fibrous areas, as in Case 14 of this series, which show no characteristic features (Fig. 13). Such a vagary may be found in many tumors of specific cell origin and in the opinion of the writer simply represents the ability of such cells to assume the guise and function of fibroblasts.

The question arises as to whether or not any of the striated muscle cell tumors of skeletal muscle can be considered benign like those which develop in the heart muscle. The latter are highly specialized relatively well-differentiated growths which are considered congenital malformations by many since they are frequently associated with tuberous sclerosis and kidney tumors and cysts. In the other muscles, however, while a relatively high degree of differentiation, as in Case 9 (Fig. 5), may indicate slow growth, it is no guaranty that it may not infiltrate so that complete removal will be difficult as in Case 11 (Fig. 9). Therefore, while it can be surmised that a tendency to differentiate may be a favorable sign all of these peripheral tumors are malignant to some degree and should, therefore, be classified as rhabdomyosarcomas.

It is impossible to avoid reference in this connection to three other varieties of muscle tumors. Abrikossoff's myoblastic myoma, otherwise known as the granular cell myoblastoma, has been very generally accepted as a tumor of immature myoblasts. Howe and Warren, using the name myoblastoma for them, have indicated that they should be segregated as a group separate from the rhabdomyosarcomas. The writer is willing to agree with this for the present, at least, for the exact nature of these tumors is not yet settled. Tissue culture studies by M. R. Murray in this laboratory have so far failed to prove beyond peradventure the myoblastic nature of these cells. The writer is not in entire agreement with all Howe and Warren have to say about malignant granular cell myoblastomas, for he believes they have included with them some rhabdomyosarcomas; an action which in his opinion serves to confuse rather than to clarify (Ravich, Stout and Ravich).

In addition to the granular cell tumors there have been described some tumors which seem to partake of the characteristics of both smooth and striated muscle cells and others in which it seems impossible to decide whether they are smooth or striated muscle cell tumors. This question has been extensively debated by Roskin, Montpellier, and others. The most confusing pictures are furnished by some uterine tumors in which both smooth and striated muscle cells are found (Lochrane). The writer has not encountered such cases arising in the skeletal muscles and he doubts if there can be many in which such equivocal conditions exist. He is inclined to simplify his nomenclature of the muscle tumors to the following terms: Smooth muscle

cell tumors—leiomyoma, leiomyosarcoma; striated muscle cell tumors—granular cell myoblastoma (benign and malignant types); rhabdomyoma of the heart muscle; rhabdomyosarcoma; undifferentiated myosarcoma (this term to be used only when it is impossible to place the tumor in any of the other groups). Most of the granular cell tumors and the heart rhabdomyomas are benign, while all of the other striated muscle cell tumors are either definitely or potentially malignant. The tumors, for instance, which arise in the genito-urinary system of infants and very young children rarely metastasize but they demonstrate stubborn infiltrative growth, and even most radical surgical procedures have failed to eradicate them.

The tumors with which the rhabdomyosarcoma is most easily confused are liposarcomas and fibrosarcomas. The liposarcomas commonly form bizarre giant cells but the nuclei are very apt to be pyknotic and lipoid droplets are always demonstrable in some part of the growth. It is sometimes mistaken for a fibrosarcoma because the cells are often elongated and connective tissue fibers are usually present between them. But the presence of bizarre giant cells in the writer's opinion definitely removes the growth from the fibrosarcoma class and means that it is in fact derived from some other specialized cell such as the lipoblast, osteoblast, rhabdomyoblast, Schwann cell, *etc.* The differential diagnosis of peripheral soft part tumors is always a challenge to the diagnostic acumen of the pathologist.

Etiologic Factors.—There is a very slight preponderance of males. Among 114 patients whose sex is recorded, there were 62 males and 52 females. The age variation is extreme, as Graph I shows, with the preponderance in the fifth and sixth decades. The mean age was 42.1 years at the time of diagnosis. Of the 116 cases whose age is known, 46 were below the mean. There are no facts suggesting immunity or higher susceptibility in any race or geographic area. Trauma of some degree is mentioned in the histories of 14 tumors or 11.5 per cent (Table Cases 1, 11, 16, 19, 32, 43, 55, 70, 87, 88, 90, 110, 111, 120). This would hardly seem a figure of significance.

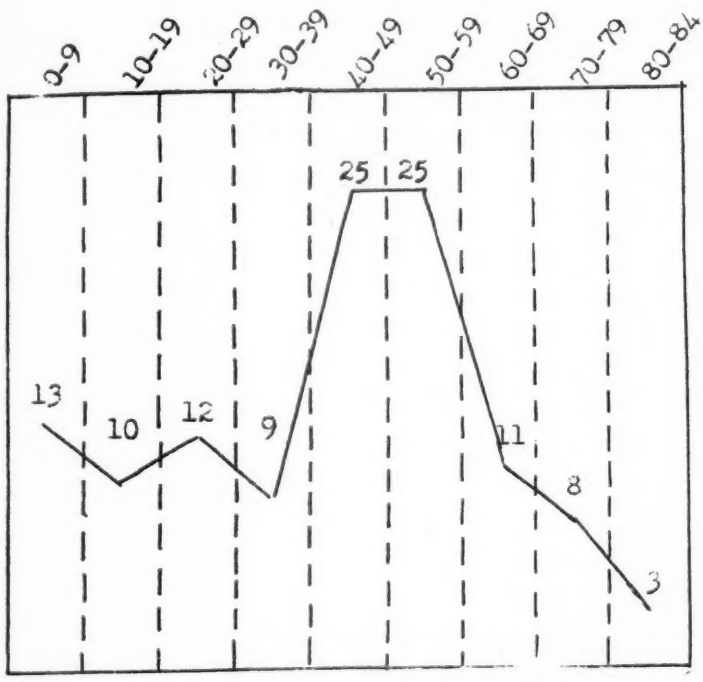
Site of Origin.—In almost every case the tumor developed either within or attached to a peripheral striated muscle. Since Case 78 had two apparently independent tumors in the thigh and axilla and Case 100 tumors in both arms, the distribution of 123 tumors from the 121 cases will be recorded. Lower extremity: 52 cases (thigh 33, leg 18, foot 1); upper extremity: 17 cases (arm 9, forearm 7, and hand 1); trunk: 31 cases (back 11, chest 8, buttock 6, groin 4, abdominal wall 2); head and neck: 19 cases (tongue 10, neck 6, head 3); diaphragm: 3 cases; psoas muscle 1. As is the case with other malignant tumors of the soft parts and bones, the thigh and leg are the favored sites of origin.

Duration of Disease.—In 48 cases the total duration of disease is known from the onset of symptoms until death. The mean is 30.25 months, with the extremes of two months (Case 90) and 162 months (Case 20). If two extremely long survival cases are omitted (Cases 20 and 93), the mean for the remaining 46 is only 24.9 months. There are, however, several other cases of very long duration of the tumor in which the total duration is not

known. Since they are referred to later in this paper attention will be directed only at this point to Case 38, with a reputed duration of 50 years. It is evident that one must be very cautious in predicting the probable duration of one of these tumors.

GRAPH I

Age Distribution of 116 Cases of Rhabdomyosarcoma of Muscles and Soft Parts



Mean Age—42.1 years. Variation 0–84

Symptoms.—Commonly the only symptom is tumor which in 88.5 per cent developed without any history of antecedent trauma and often without pain or interference with function. Increase in size is sometimes rapid and sometimes extremely slow and a considerable bulk may be attained although not as a rule the massive proportions of many liposarcomas. The deep situation and muscular involvement produce a moderately firm deep-seated mass, which is of very limited mobility. Sometimes growth of the tumor compromises the overlying skin and the tumor fungates. This may also happen after biopsy. The appearance is shown in Figures 3 and 12.

Gross Characteristics.—The tumor tissue varies greatly in its hardness because of the great variation in the amount of collagen in it. Generally it is rather soft, somewhat reddish and may be mottled with various tints of red and cream from hemorrhage and necrosis. It is often circumscribed but always infiltrates surrounding tissues, although it is not always possible grossly to demonstrate this.

TABLE I

RHABDOMYOSARCOMA

REPORTED AND PERSONAL CASES

Author	No.	Sex	Age	Site	Dur* A.T.	Excision 1	2	3	4	5	6	7	13	Ampu-tation	Other Op.	Pre-op. Rad.	Post-op. Rad.	Rad. Alone	Re-cur.	Met-as.	Dead	Alive Tumor	Alive ⊼ T.	Total Dur. Mos.
Ammunategui	1	F	5	Glut. max.		+													+	+	+			
Ardoin	2		3	Temp. mast.		+													+		+(6)			6
Benison (Case 7)	3	F	23	Coraco-brach.	7									+inter-scap.	+ (biop.)	+							+(0)	
Bérard	4	M	2	Back		+									+(pal)				+		+(18)			
Billroth	5	F	Ad.	Arm	6	+	+	+											+			+(18)		
Bolanos	6	F	12	Tongue	12	+									+(biop.)	+							+(0)	
Buhl																								
(1)	7	F	28	Sacral		+													+			+(0)		
(2)	8	M	50	Chest		+													+			+(0)		
Burgess	9	F	19	Thigh, muscle																+	+			Few
Cappell (6)	10	M	60	Tongue		+	+	+									+		+	+	+			48
Charache	11	M	44	Thigh	6	+											+		+	+	+			12
Danciger & Warren	12	M	2	Gastroc.																+	+			18
De & Tribendi																								
(1)	13	F	46	Thigh		+	+										+		+	+	+			43
(2)	14	M	13	Axilla	12	+																	+(48)	
(3)	15	M	38	Hand	60	+								+			+		+		+(24)			84
(4)	16	F	20	Back muscles	11	+	+	+									+		+			+(96)		
(5)	17	M	39	Thigh	3	+											+					+(3)		
(9)	18	M	50	Arm																	+			24
(11)	19	M	48	Thigh	144									+						+		+		
(12)	20	M	45	Tongue	108	+	+	+									+		+		+			162
(13)	21	M	11	Leg	36									+									+(0)	
De Castro-Freire	22		½	Tongue	6	+																	+(0)	
Desmarest & Masson	23	M	80	Thigh	3	+																	+(0)	
Engelbreth-Holm	24	M	75	Neck																+	+			24
Fitzwilliams	25	M	62	Thigh	3									+ hind-qrtr.									+(0)	
Frank, *et al.*	26	F	40	Neck	132	+	+										+		+				+(36)	
Fuginami	27	M	50	Leg	120									+									+(0)	
Genevet																								
(1)	28	M	32	Leg		+															+(3)			
(2)	29	F	50	Thigh		+															+(6)			
(3)	30	F	22	Leg																				

TABLE I—*Continued*

RHABDOMYOSARCOMA
REPORTED AND PERSONAL CASES

Author	No.	Sex	Age	Site	Dur* A.T.	Excision: 1	2	3	4	5	6	7	13	Ampu-tation	Other Op.	Pre-op. Rad.	Post-op. Rad.	Rad. Alone	Recur.	Meta-s.	Dead	Alive Tumor	Alive & T.	Total Dur. Mos.
Geschickter																								
(2)	31	M	63	Forearm		+													+			+(36)		
(3)	32	M	17	Leg	2									+									+(132)	
(4)	33	F	44	Sacral		+	+										+		+	+		+		
Glasunow																								
(3)	34	M	74	Thigh	12	+	+												+				+(0)	
(4)	35	M	32	Leg	7									+		+							+(0)	
(5)	36	F	18	Thigh	24									+(dis-art.)	+				+	+		+		
Halley	37	M	40	Calf	60	+											+			+				
Harper & Feder	38	M	75	Neck	600	+													+			+		
Johan Jönsson	39	F	44	Arm	5	+	+												+				+(0)	
(1)	40	F	65	Back	6	+	+	+									+		+		+(116) No tumor			
(2)	41	F	55	Thigh	2	+	+									+	+		+	+	+			53
(3)	42	M	78	Groin											+(pal.)			+			+			15
(4)	43	F	45	Gluteal														+			+			
(5)	44	M	47	Leg		+	+												+		+(60)			
(6)	45	F	44	Chest		+	+	+	+	+	+	+							+		+(38)			
(7)	46	M	57	Arm	24	+								+(dis-art.)			+		+	+	+(22)			46
(8)	47	M	55	Thigh		+	+										+		+		+(suicide)			
(9)	48	F	48	Thigh	6	+											+		+	+	+(16)			22
(10)	49	M	57	Thigh	1									+(dis-art.)			+		+	+	+(5)			6
(11)	50	F	36	Thigh	24										+(pal.)			+	+	+	+(26)			50
(12)	51	F	64	Leg	3	+											+		+	+	+(11)			14
(13)	52	M	57	Thigh, gluteal	10													+	+		+(4)			14
(14)	53	M	56	Leg	1	+								+			+		+	+	+(7)			8
(15)	54	M	80	Leg	1½													+	+		+(34½)			36
(16)	55	M	48	Knee	8									+		+					+(2)			10
(17)	56	F	28	Chest	2	+										+	+						+(71)	
(18)	57	F	59	Leg	7									+		+				+	+(19)			26
(19)	58	F	52	Abd. wall	1½	+	+										+		+	+	+(6)			7½
(20)	59	F	57	Thigh	3													+	+		+(34)			37
(21)	60	F	48	Thigh	3													+	+	+	+(15)			18

TABLE I—*Continued*

RHABDOMYOSARCOMA

REPORTED AND PERSONAL CASES

Author	No.	Sex	Age	Site	Dur* A.T.	Excision 1	2	3	4	5	6	7	13	Ampu-tation	Other Op.	Pre-op. Rad.	Post-op. Rad.	Rad. Alone	Re-cur.	Met-as.	Dead	Alive Tumor	Alive - T.	Total Dur. Mos.
(22)	61	F	63	Groin	6													+	+		+(3)			9
(23)	62	F	45	Thigh	24	+										+			+	+	+(18)			42
(24)	63	F	57	Gluteal	3	+											+		+		+(26)			29
(25)	64	F	16	Thigh		+	+										+		+	+	+(7½)			
(26)	65	M	78	Back	1	+	+	+	+								+		+			+(49)		
(27)	66	M	77	Groin	18	+										+					+(art-scleros. (8)			
(28)	67	F	52	Thigh	1	+	+										+		+	+	+(78)			79
(29)	68	F	41	Abd. wall	4	+											+		+			+(30)		
(30)	69	M	69	Gluteal	3	+											+		+	+	+(12)			15
(31)	70	F	28	Thigh	10	+										+	+					+(24)		
(32)	71	M	48	Forearm	18	+	+										+		+	+	+(10)			28
(33)	72	M	30	Thigh	5½	+										+	+			+	+(12)			17½
(34)	73	F	47	Back	1	+											+						+(18)	
(35)	74	M	46	Thigh	18	+											+						+(18)‡	
(37)	76	F	52	Leg	6									+		+					+(p. op.)			
(38)	77	F	53	Thigh	4	+	+										+		+	+		+(27)		
(39)	78	F	58	Thigh and axilla	44 36	+											+						+(12)	
Kirschbaum (1)	79	M	47	Diaphragm																+	+			3½
Lepage	80	M		Submax.		+	+												+				+(84)	
Ligas	81	M	53	Thigh	5	+																	+(0)	
Lino	82	F	24	Tongue		+																	+(0)	
MacCallum (1)	83	M	59	Arm	1	+	+	+						+(dis-art.)					+	+	+(pul. emb.)			5½
(2)	84	F	70	Leg	12	+													+		+(46)			58
Marchand	85		4	Gluteal																				
Von Meyenburg	86	M	57	Tongue		+	+												+		+			13+
Muller	87	M	48	Thigh										+(dis-art.)									+(0)	
Ono	88	M	24	Forearm	1	+	+							+					+				+(0)	
Oswald	89	M	36	Neck	36±	+													+	+	+(4)			
Peery & Smith	90	M	14	Diaphragm	2															+	+			2
Pendl	91	M	0	Tongue	2	+																	+(0)	
Rakov (7)	92	F	47	Arm		+	+	+	+	+	+								+			+(132)		

TABLE I—*Continued*

RHABDOMYOSARCOMA
REPORTED AND PERSONAL CASES

Author	No.	Sex	Age	Site	Dur* A.T.	Excision 1	2	3	4	5	6	7	13	Ampu-tation	Other Op.	Pre-op. Rad.	Post-op. Rad.	Rad. Alone	Re-cur.	Met-as.	Dead	Alive Tumor	Alive ō T.	Total Dur. Mos.
(12)	93	F	48	Arm		+	+	+	+	+	+	+	+	+(inter-scap.)					+	+	+(12)			144
Ribbert																								
(1)	94			Temporal		+																	+(0)	
(2)	95	M	boy	Face		+													+			+		
Richmond																								
(1)	96	M	45	Thigh	36	+											+		+	+	+(8½)			44½
(2)	97	F	59	Thigh	9									+	Biop.						+(P.O.)			
Rutz	98		0	Tongue	5	+																	+(0)	
Ryan	99	F	51	Diaphragm	2															+	+			4¼
Scott-Carmichael	100	M	56	Arm (bilat.)	3	+																	+(4)	
Stulz, *et al.*	101	M	66	Forearm	12	+	+												+				+(0)	
Targett	102		0	Neck	6	+	+												+				+(6)	
Thomas	103		4½	Tongue	12	+	+	+	+	+	+								+		+(8)			20+
Tourneux & Gouzi	104	F	21	Psoas		+																		
Warnery	105	F	7½	Back																				
Weber	106	M	21	Tongue		+													+			+(0)		
Wolbach	107	F	4	Back	1½	+													+		+(4)			5½
Columbia Univ.																								
(1)	108	M	22	Thigh	4									+(dis-art.)	Biop.	+				+	+(2)			6
(2)	109	M	21	Leg	8									+	Biop.	+				+	+(3)			15
(3)	110	M	47	Thigh	7										Biop.			+	+		+			16
(4)	111	F	19	Leg	1	+	+	+						+					+	+	+(35)			49
(5)	112	F	35	Back	5										Biop.			+	+			+(8)		
(6)	113	M	75	Gluteal	6										Biop.			+	+	+	+(8)			14
(7)	114	F	63	Forearm	9										Biop.						+			39
(8)	115	M	56	Thigh											Biop.						+(4)			
(9)	116	F	33	Arm	¼	+																	+(60)	
(10)	117	M		Forearm	12	+									Biop.				+			+(6)		
(11)	118	F	15	Back	5±	+	+ (25)																+(51)	
(12)	119	M	53	Axilla	½										Biop.							+(0)		
(13)	120	M	69	Chest wall	5	+	+ (6)										+				+(12)			
(14)	121	F	66	Foot	32	+								+(14)					+				+(0)	

* Duration before treatment.

All duration figures are recorded in months.

Spread.—The insidious character of the local invasive spread of the tumor is indicated by the high incidence of local recurrence after treatment, 108 cases received some kind of an attempt at curative treatment. Local recurrence was noted in 66, or 61 per cent. Spread also takes place through the blood and lymphatic systems. Thirty-eight patients are known to have had metastases. The site of these was as follows: Lungs 23, lymph nodes ten, skin and subcutaneous tissues eight, pleura seven, bones five, liver three, kidney, suprarenal mediastinum and pericardium two each; pancreas, ovary and brain, one each. Metastases were generalized in only five cases.

Duration of Tumor before Treatment.—This is recorded in 84 cases, and the mean duration for these is 23.2 months. But five cases had an inordinately long duration of from nine to 50 years before treatment was undertaken. If these are omitted, the other 79 cases had a mean duration of 10.7 months, with a variation from a few days to five years.

Treatment.—Reference to Table I will show that many different ways of dealing with these tumors have been employed. These have consisted principally of simple excision, amputation and, to a less extent, radiotherapy. Often two or all three methods have been employed. In so far as *radiotherapy* is concerned, it has been used as the sole method of treatment in 12 cases, without any good results. In all the tumor persisted and in ten the patient is known to have died. Preoperative radiation was used in 14 and postoperative radiation in 35 patients. Since operations were also performed, one cannot know whether or not the radiation had any important effect. It seems very questionable that it did. Postoperative radiation was used in Case 40 and failed to prevent a local reappearance of the tumor. When this was removed by electrocoagulation the patient then remained free of tumor for nearly ten years before dying of complications following a fracture. In Cases 66, 73, 74 and 78, the patients were symptom-free for eight, 18, 18 and 12 months after excision and radiotherapy but there is no further information about them and the periods are too short to be significant. Stewart found that the few rhabdomyosarcomas treated by radiotherapy at the Memorial Hospital were resistant. We may conclude that the tumor is certainly little affected by ordinary doses. Whether or not huge doses pushed to the limits of tolerance would accomplish anything more important remains to be determined.

The first treatment of 80 cases was an attempt at local excision of the tumor. Twelve of these were not followed and five more were without evidence of tumor less than five years (at 48, 8, 18, 12 and 4 months). Only two remained well five or more years. Case 56 had a tumor of the chest wall below the clavicle which grew rapidly for two months and was treated by excision with pre- and postoperative radiotherapy. When last seen, 71 months after operation, she was symptom-free. Case 116 had a small tumor excised from within the triceps muscle only one week after the tumor was found. Five years afterwards there was no evidence of recurrence. Of the remaining 63 patients all had recurrence or metastases and 36 had subsequent operations, either further excisions (to the number of 13 in Case 93) or amputation or both. Of these all but three are dead or were last seen with tumor persisting.

Case 26 had a 6 x 5 cm. tumor in the neck deep to the muscles for 11 years. It had eroded the vertebrae and reached the spinal canal, producing pressure symptoms. Excision was incomplete and after one month a second excision was done supplemented by radium in the wound and postoperative roentgenotherapy. Three years later there was no evidence of recurrence. Case 102 was also in the neck and was congenital. It was incompletely removed from its deep situation and a second excision was carried out one month later. Six months after the second operation the child was well. Case 118 is Case 11 reported in this paper. Twenty-five months after removal of the primary tumor from the rhomboideus muscle a recurrence was excised, and 51 months after the second operation she was well. With these should be mentioned Case 40 who died of injuries and was without evidence of persistence nine and two-thirds years after the last of three attempts to remove a tumor of the back.

Primary amputation or amputation after biopsy was carried out 16 times. Seven were not followed, two died as a result of the operation, six had recurrences or metastases and only one had a good result. This is Case 32, which had a primary amputation for a tumor of the leg and was reported well 11 years later.

Of the 13 remaining cases, there was either no treatment or there is none recorded.

There are several cases of long survival with the tumor persisting which should be noted. Tumor persistence of nine years is noted in Cases 16 and 20, ten years (Case 27); 11 years (Case 92); 12 years (Case 19); 13⅔ years (Case 20); 14 years (Case 26); and 50 years (Case 38). It is quite evident, therefore, that rhabdomyosarcoma may persist for a very long time without killing.

From the above data it will be appreciated that it is impossible arbitrarily to select the best form of treatment, since of four long survivals without evidence of persisting tumor one (Case 32) was treated by primary amputation alone; one (Case 116) by simple excision alone; one (Case 56) by simple excision with pre- and postoperative radiotherapy; and one (Case 40) by excision and postoperative radiotherapy followed by two subsequent excisions of recurrences. It is manifest, however, that in a very large number of cases the first procedure was an inadequate excision and one should be able to cure this neoplasm more often if it is attacked earlier and in a more radical manner. Long study of cases of malignant tumors of the peripheral soft parts and bones has convinced the writer that they should not be attacked by blind removal before obtaining definite knowledge of their nature by biopsy. If the tumor is treated without knowledge of its nature one runs the hazard of removing too much or too little; usually the latter. A small biopsy removed with the minimum amount of trauma will furnish the information necessary for proper action and of itself will do no harm. In the case of the rhabdomyosarcoma, treatment should certainly be radical with removal of a large block of surrounding uninvolved tissues. This may or may not mean amputation.

CASE HISTORIES

Case 1.—(Table No. 108): M. C., male, Jewish presser, age 22, was first seen at the Presbyterian Hospital, October 14, 1921. He had noted a swelling the size of a hen's egg on the inner aspect of the right thigh for three months, which appeared without history of injury. It was hard, freely movable, and painless until two weeks before admission. It increased rapidly in size so that on admission the circumference of the right thigh was 48 cm. in comparison with 39 cm. for the left. The swelling of the thigh was diffuse and extensive measuring 24 x 14 cm. Wassermann reaction negative. Roentgenograms showed a soft-part tumor without bony involvement. Aspiration yielded only blood. October 21, 1921, a biopsy was taken which was diagnosed as a malignant sarcoma. The wound did not heal well because the tumor grew up into it. The patient refused amputation. A small amount of low voltage roentgenotherapy was given to the thigh and to the chest after roentgenograms of the lungs, November 2, 1921, showed shadows suggestive of pulmonary metastases. A secondary metastatic mass appeared on the anterior surface of the right leg. Because of pain and ulceration the patient consented to disarticulation of the right hip November 15, 1921. The pulmonary metastases enlarged rapidly, and he died January 9, 1922.

Grossly (S. P. 26812) the tumor was 32 cm. in length with a maximum thickness of 8 cm. where it ulcerated through the skin. It was soft orange-pink with areas of hemorrhage. It involved the vastus medialis muscle but not the bone. In the leg anteriorly were two secondary subcutaneous nodules of similar appearance.

Microscopic: Very large strap cells with hyperchromatic nuclei often in tandem arrangement. Occasional rounded giant forms. Much blood pigment. No longitudinal or cross-striations and no vacuolated spider cells seen. Cytoplasm moderately acidophilic. (No special stains available.)

Case 2.—(Table No. 109): R. L., white American farmer, age 21, was admitted to the Presbyterian Hospital, July 16, 1932. He had noticed, by chance, a painless, egg-sized swelling of the lateral side of the right calf at the midpoint of the leg eight months before. Five months before it began to be painful after he had been walking. Fifteen days before a biopsy was taken elsewhere and called a mixed cell sarcoma. Examination showed a 6 x 8 x 12 cm. mass in the outer part of the right gastrocnemius muscle. Roentgenotherapy was begun July 18, 1932, and carried on sporadically until October 15, 1932. Large fields were used (15 x 20, 20 x 20, and 15 x 15 cm.), 180 to 200 KV; 50 cm. A. S. D. and filtration 0.55 Cu. plus 1, mm. Al. A total of about 8,520 r was given through the various fields to the leg. Toward the end of this period two nodules appeared in the popliteal space which were biopsied November 17, 1932, and proved to be metastases. The extremity was amputated through the midthigh November 23, 1932. Following this he had a great deal of pain in the right groin and right lower quadrant with enlarged tender inguinal nodes. Roentgenograms of spine and chest showed no evidence of metastases. Cordotomy for relief of pain was contemplated, but before this could be arranged the level of the pain had ascended so high that this was abandoned. He died at home, February 11, 1933.

Gross (S. P. 49920) (Fig. 1): The tumor measured 7 x 8.5 cm., it lay within the gastrocnemius and soleus muscles. The cut-surface was grayish mottled with red areas of hemorrhage and yellow areas of necrosis. There were four other separate nodules in these muscles and others in the tibialis anticus and the popliteal space.

Microscopic: The tumor is much altered by the radiation which has produced widespread degeneration, necrosis and fibrosis. Where the cells have escaped they appear as large strap forms with nuclei in tandem, acidophilic cytoplasm and occasionally well-defined longitudinal intracellular fibers. No cross-striations discovered. Many cells are vacuolated. Rare giant cells but no spider forms.

Case 3.—(Table No. 110): R. P., a colored dining-car waiter, age 47, first came to the Presbyterian Hospital April 12, 1934. Four years before he hurt his left thigh by stepping into a coal pit, resulting in pain in the medial thigh muscles. Ten months

before he struck the same thigh against a dining-car table. Pain began seven months before, and swelling was first noticed one month later. Gradual increase of symptoms causing some limp. Examination showed a 15 x 20 cm. hard mass in the middle of the left thigh apparently in the vastus medialis muscle (Fig. 2). Not tender and only slightly movable. Wassermann reaction and roentgenograms of thigh and chest negative.

FIG. 1.—Case 2 (Table No. 109) : Rhabdomyosarcoma of gastrocnemius muscle showing secondary nodules.

He was admitted and a biopsy done April 26, 1934. This showed a pale elastic tumor mass deep to the vastus medialis which exuded serous fluid when the biopsy cut was made. The inguinal and femoral nodes were not enlarged. He was treated by a large radium pack with 43 tubes containing from 5 to 12.5 mg. radium totalling 350 mg. The pack was left on for seven days and a dose equivalent to 50,000 r given. This was done May 5, 1934 to May 11, 1934. It was supplemented by 2300 r of high voltage high filtration roentgenotherapy given through anterior and two lateral ports sporadically from April 30, 1934, to October 1, 1934. The mass decreased in size somewhat but never disappeared.

Evidence of spread or metastasis was never obtained but the pain returned, grew much worse, and he died at home February 21, 1935.

Microscopic.—(S. P. 54161): Rather large irregularly-shaped cells with finely granular acidophilic cytoplasm. No longitudinal or cross-striations. Some strap forms with nuclei in tandem arrangement. No giant cells but some cells with vacuoles.

Case 4.—(Table No. 111): M. L., a white American secretary, 19 years old, Eighteen months before coming to the hospital she bruised her right knee but was able to continue work. Four months later she noticed a swelling over the right shin at the site of a spot which she often used to push in the lower drawer of a filing cabinet. It was the size of a quarter and not discolored. A physician excised it in his office one month later. It recurred in two months and was again locally excised. This wound never healed, and after three months it was excised for the third time four months before admission. This wound also failed to heal, and when admitted there was a multinodular fungating growth elevated 2 cm. above the surface and measuring 11 cm. vertically and 7 cm. transversely (Fig. 3). Roentgenograms showed no lung metastases. December 9, 1937, a supracondylar amputation was done through the lower third of the thigh. She remained well until March 1, 1939, when evidences of lung metastases appeared. Roentgenograms, July 15, 1939, showed a large mass in the left upper lobe. Two months later this had doubled in size but the girl felt relatively well and remained active until September, 1940. A large recurrent tumor mass then appeared above the amputation site and metastatic nodules in the mammary and clavicular regions. She died at home, November 16, 1940, 35 months after amputation.

FIG. 2.—Case 3 (Table No. 110): Rhabdomyosarcoma of vastus medialis muscle.

Gross (S. P. 65768) (Fig. 3): The tumor involved the tibialis anticus, extensor longus digitorum and peroneus longus muscles. It was pinkish in color with hemorrhagic areas, and had a maximum thickness of 4 cm. Two popliteal lymph nodes showed no tumor.

Microscopic (Fig. 4): The tumor is composed of bundles of large spindle and strap cells with moderately acidophilic cytoplasm, sometimes granular and sometimes showing longitudinal striations. Cross-striations are demonstrated with difficulty because they rarely traverse the cell completely. Giant cells are occasionally present, some of which are vacuolated.

Case 5.—(Table No. 112): L. W., a Jewish woman, age 35, was admitted to the Urologic Department of the Presbyterian Hospital, complaining of five months back pain more severe on the right side. It grew constantly worse, with loss of 15 pounds weight. Examination showed an elastic nonfluctuant mass to the right of D 10 and D 11. It was rigidly attached to the ribs. Roentgenograms showed erosion of the eleventh rib posteriorly. She was transferred to the Fracture Service, and explored December 28, 1937. The tumor was grayish-white with dark hemorrhagic areas. The muscles were infiltrated and the ribs surrounded with tumor penetrating inside the thoracic cage. It

extended transversely from just to the right of the midline to the posterior axillary line. Biopsy was taken and roentgenotherapy started January 3, 1938, and continued to February 3, 1938. The factors were: 200 KV, 25 MA, TSD 50–80 filters varied from 0.5 to 2 mm. Cu. The fields were direct posterior and right and left tangential varying from 10 x 20 to 15 x 15 cm. Twenty-seven daily treatments totaling 400 r direct and 3,000 r to each of the two tangential fields. The treatment had little effect and the

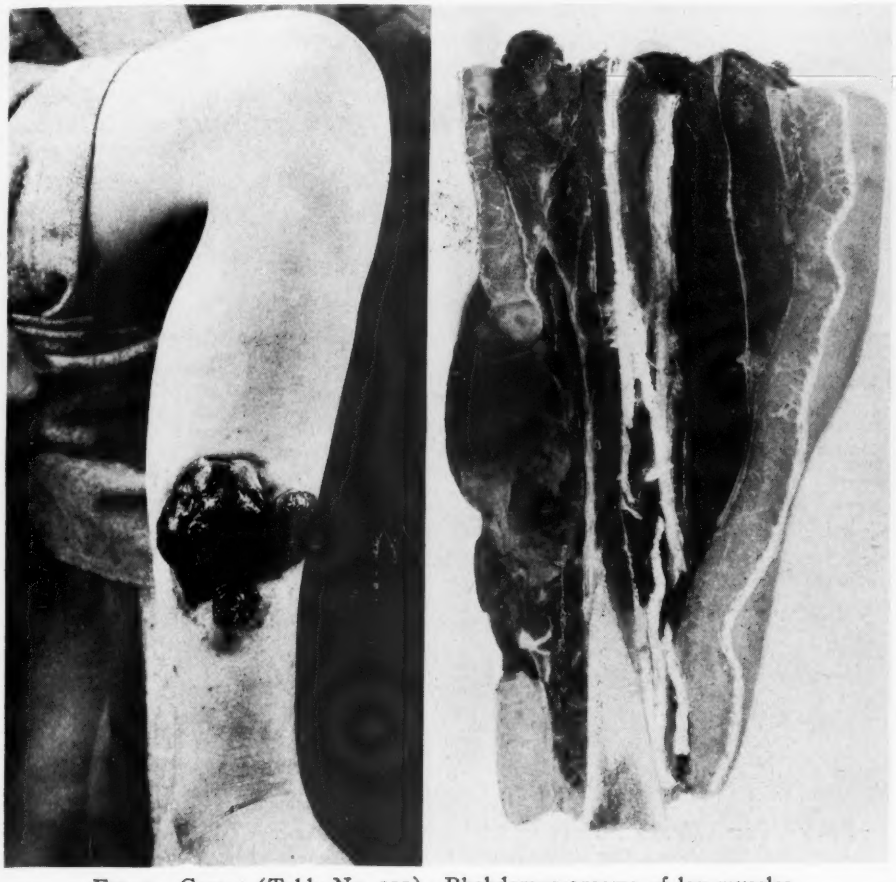


FIG. 3.—Case 4 (Table No. 111): Rhabdomyosarcoma of leg muscles.

last note stated that eight months after operation she had gone down hill rapidly and would probably soon be dead.

Microscopic (S. P. 65925) (Fig. 5): There are bizarre and strap cells with many longitudinal fibers best shown with Heidenhain's hematoxylin and phosphotungstic acid. Acidophilic intracellular granules sometimes suggest an abortive attempt to form cross striations. There are a few giant cells but no spider forms. There is a well developed connective tissue framework.

Case 6.—(Table No. 113): W. S., white, male, age 75. Six months before admission, without known cause, an area of soreness developed below the flexion crease between the right thigh and buttock. One month before a mass was noted. It lay just caudad to the right ischial tuberosity, measured about 8 x 6 cm., and was apparently deep to the fascia. Roentgenograms of chest and skeleton were negative. Aspiration was done November 14, 1938, yielding soft, gray bloody tissue. Roentgenotherapy was started November 12, 1938, and estimation of the size of the mass at this time was 12 x 14

cm. The factors were: 200 KV, 25 MA, 50 TSD, filter 1 mm. Cu plus 1 mm. Al. The fields were superior delivered in the kneeling position through the buttock receiving 3,000 r, and two lateral fields each of which received 2,000 r. Treatments continued daily from November 12, 1938, to December 22, 1938. Evidence of pulmonary metastases developed April 24, 1939, and he died July 4, 1939.

Microscopic (S. P. 68906): The few tumor cells present in the small biopsy are for the most part irregularly rounded and very variable in size with occasional multinucleated giant cells. Some of these have marginal vacuolation of the cytoplasm producing the so-called "spider" effect. No longitudinal or cross-striations are recognized. The cytoplasm is slightly acidophilic and without granules.

Case 7.—(Table No. 114): D. F., an Austrian Jewish widow, age 63. Fourteen years before this woman had had a right radical mastectomy for carcinoma, without axillary metastases. She was apparently cured of this. Nine months before her second

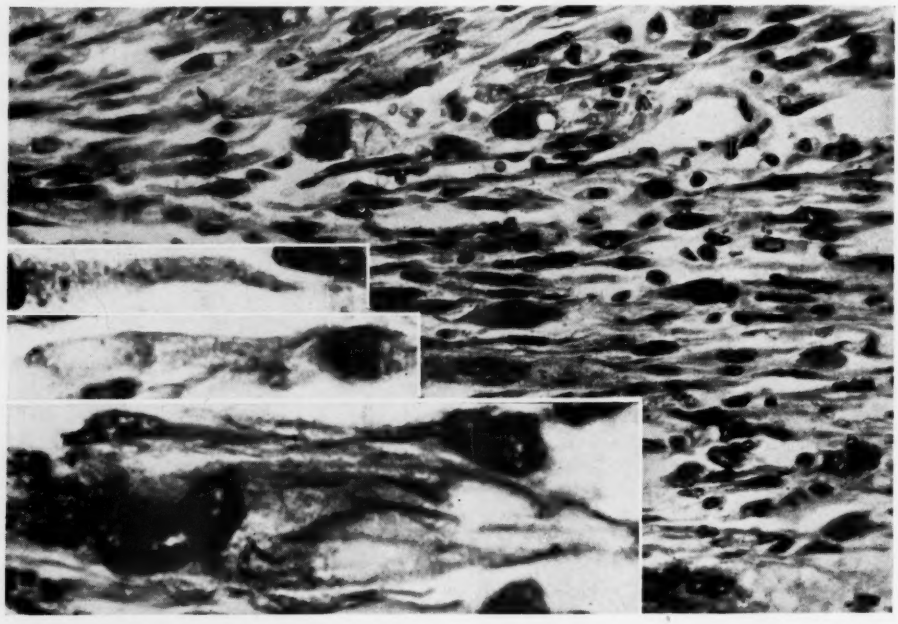


FIG. 4.—Case 4 (Table No. 111): Photomicrograph (x 410 and x 1240). Heidenhain's hematoxylin stain. The insets in the lower left corner show two strap cells with poorly defined cross-striations and two other cells with longitudinal myofibrils.

admission to the Presbyterian Hospital a painful swelling appeared on the outer aspect of the right forearm just caudad to the olecranon. It seemed to lie in the forearm muscles, was about 13.5 cm. in diameter and roentgenograms showed that it had eroded the outer condyle of the humerus probably by pressure. It was biopsied May 3, 1939. The woman refused all forms of treatment. The tumor slowly increased in size, ulcerated at the site of biopsy (Fig. 6) and she died at home approximately two and a half years after biopsy. Whether or not there were metastases is unknown.

Microscopic (S. P. 70542): The tumor is made up of bizarre large cells, amorphous usually but with strap syncytia formed occasionally. Giant forms are present but no spider cells. The cytoplasm is acidophilic and usually nongranular. Vague cross-striations are shown in some of the giant cells (Fig. 7).

Case 8.—(Table No. 115): M. A., a male, age 56. The only history available states that this man had a mass beneath his thigh muscles (*sic*) which was thought to be an hematoma. It was biopsied in October, 1916. In four months he was dead.

Microscopic (P & S 3689): The tumor is made up of masses of large cells of extremely varied shape, including occasional strap forms with nuclei in tandem, and more giant cells with several nuclei near the center of the cell and vacuoles in the cytoplasm. The cytoplasm is sometimes granular. Very little fibrous framework. No longitudinal or cross-striations seen but the preparation is poor and there are no special stains.

Case 9.—(Table No. 116): Mrs. J. B., a white, American female, age 33. By chance the patient felt a lump in the right posteromedial brachial region and the next day consulted Dr. R. N. Schullinger. It was painless, rounded, and could be moved from side to side, but not from above downward. It was excised from within the belly of the triceps muscle March 3, 1932. Five years later there was no evidence of recurrence.

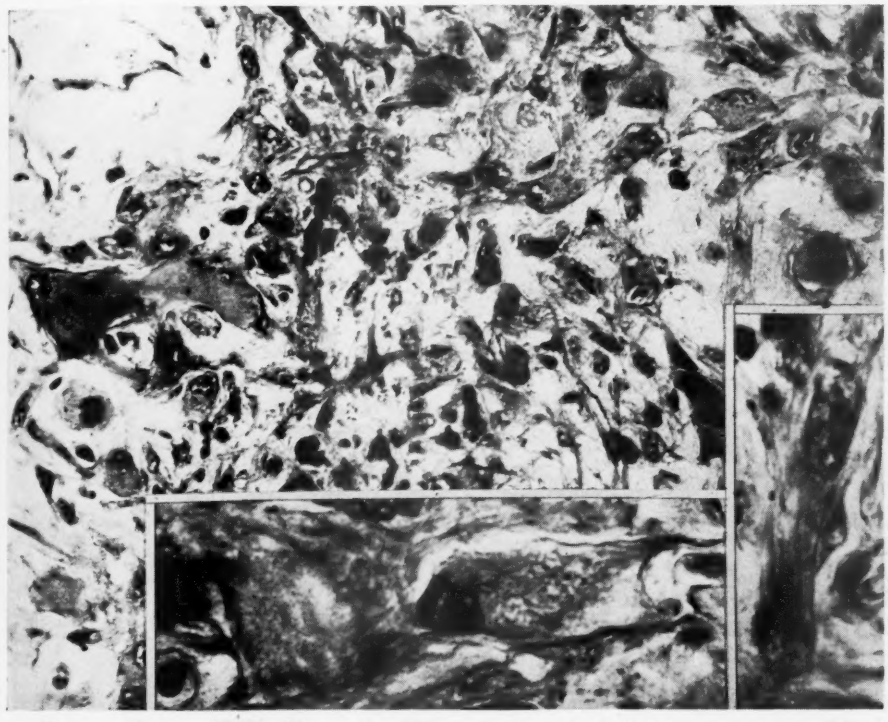


FIG. 5.—Case 5 (Table No. 112): Photomicrograph of rhabdomyosarcoma of back muscles. Heidenhain's hematoxylin stain (x 410 and x 1240). The highly magnified cell to the right shows longitudinal myofibrils and the two cells below contain granules which have an arrangement suggesting imperfect cross-striations.

Gross (S. P. 12245): A pallid, firm, pear-shaped encapsulated tumor 2 x 1 x 1 cm. The cut-surface showed a glistening white appearance with one small area of hemorrhage.

Microscopic (Fig. 8): Most of the tumor cells are small, amorphous or rounded cells with vacuolated cytoplasm. Scattered at intervals are larger rounded cells with strongly acidophilic cytoplasms which frequently show cross-striations. No longitudinal striations are seen. The nuclei are for the most part small and they do not have the sharply accentuated chromophilic markings of the more malignant and less well-differentiated rhabdomyoblastomas.

Case 10.—(Table No. 117): L. W., a male, age not stated. Eighteen months before a growth first appeared beneath the skin of the forearm. After one year it was excised but it soon reappeared, and in six months it measured 9 x 6 x 3 cm. Its surface was ulcerated. A biopsy was taken June 14, 1933, by Dr. R. N. Schullinger. The subsequent course is not known.

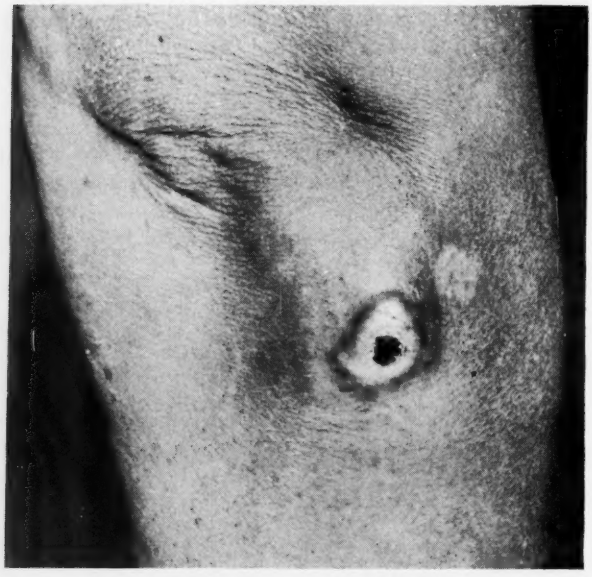


FIG. 6.—Case 7 (Table No. 114): Rhabdomyosarcoma of forearm showing biopsy site.

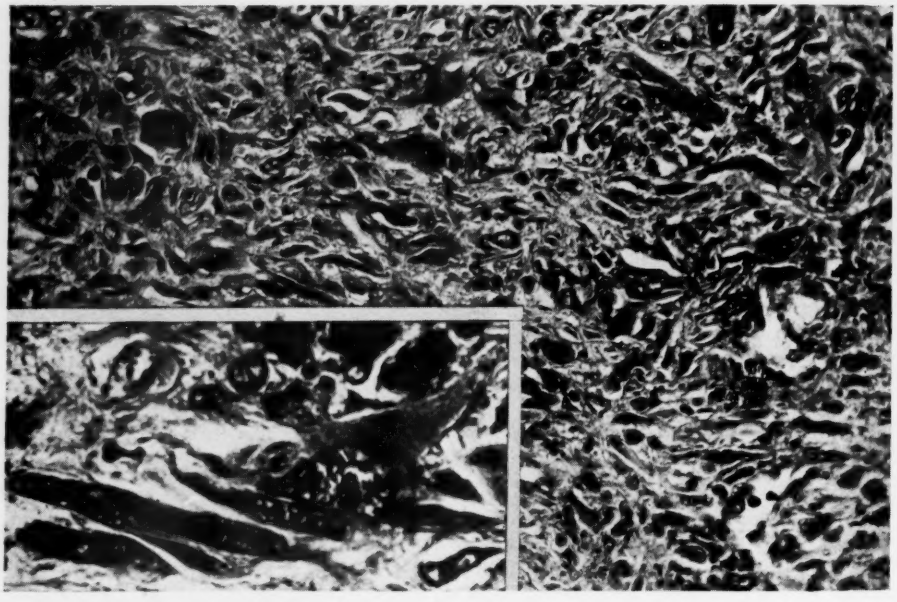


FIG. 7.—Case 7 (Table No. 114): Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. The highly magnified inset in the lower left corner shows a strap cell with nuclei arranged in tandem and a giant cell with cross-striations faintly shown.

Microscopic (P & S 12931): The biopsy is very small and from the surface. It shows a very edematous tumor in which the cells are widely separated. They are usually elongated and either have the nucleus at one end or two or more nuclei in tandem. Occasional small giant cells are seen. The cytoplasm is strongly acidophilic and either edematous or vacuolated. No definite longitudinal or cross-striations are seen.

Case 11.—(Table No. 118): F. H., a white, American schoolgirl, age 15 years. About six months before treatment she first complained of vague pain in the left shoulder region. Some three months later a lump appeared in this area and gradually increased in size. It was excised by Dr. William C. White at the Roosevelt Hospital, New York, February 3, 1939. It was 7 cm. in diameter and lay within the rhomboideus major muscle. Two years later there was a recurrence in the scar of about the same size as

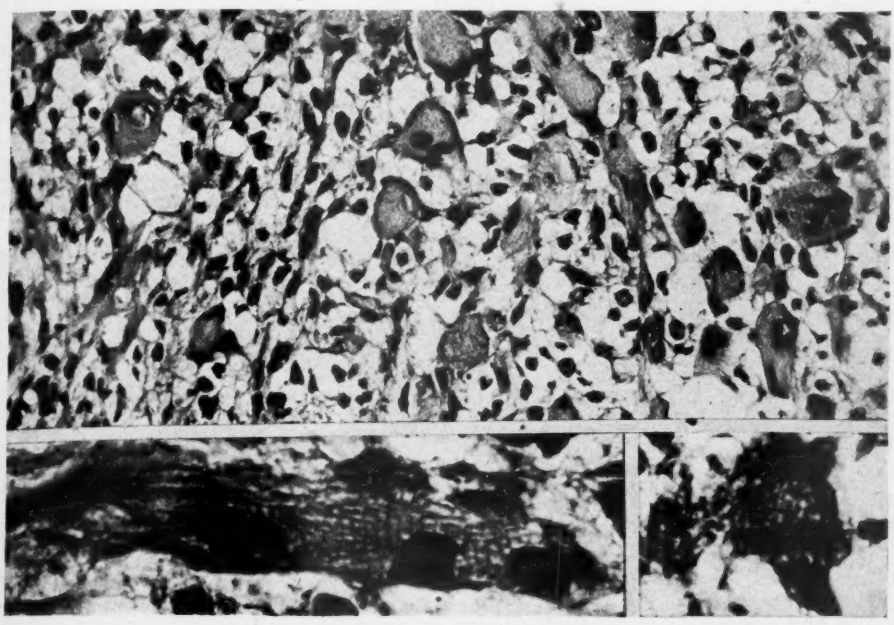


FIG. 8.—Case 9 (Table No. 116): Rhabdomyosarcoma of triceps muscle. Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. An area showing many giant cells and much vacuole formation. The highly magnified insets below show the clearly defined longitudinal and cross-striations in some cells.

the original tumor. This was widely removed, the excision including both rhomboid muscles. Roentgenograms of the chest at this time were negative. Doctor White reports that the girl was married in January, 1945, and was well at the beginning of June, 1945, 76 months after the first operation and 51 months after the second. Both of the specimens were examined by Dr. W. W. Brandes, pathologist of the Roosevelt Hospital, who recognized the neoplasm as a rhabdomyosarcoma.

Microscopic (P & S 16658): The original tumor shows long tapering cells with strongly acidophilic cytoplasm sometimes showing cross-striations but no longitudinal fibers. These are collected into bundles and interlarded with occasional rounded cells of somewhat larger size with acidophilic cytoplasm but no cross-striations (Fig. 9).

Case 12.—(Table No. 119): A male, age 53. Two weeks before he noted masses in the right axilla which measured 2 x 4 cm. A biopsy was taken in April, 1939, at the Clifton Springs Sanitarium, at Clifton Springs, N. Y., and the section was submitted to this laboratory by Dr. W. C. Sternbergh, at that time connected with the Radiologic Department of the sanitarium.

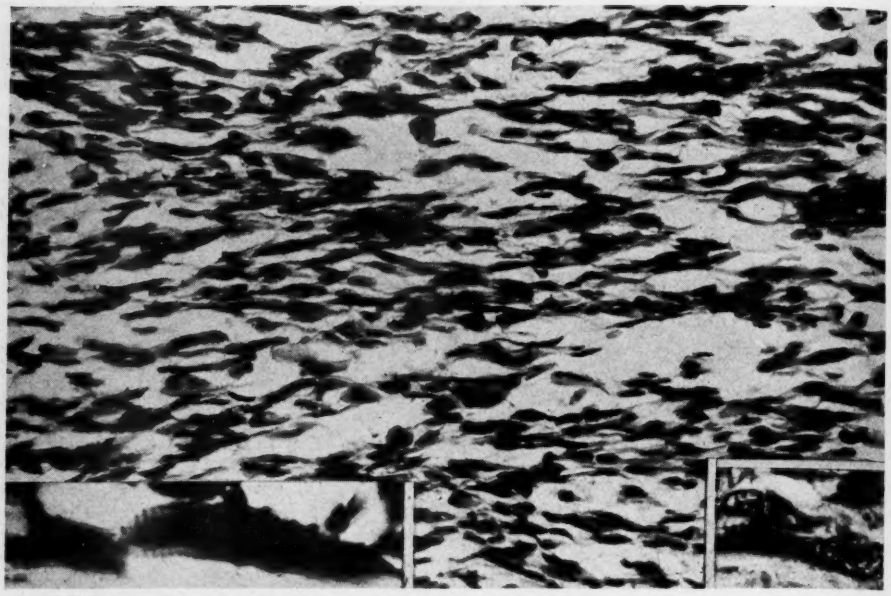


FIG. 9.—Case 11 (Table No. 118): Rhabdomyosarcoma of rhomboideus muscle. Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. The highly magnified insets below show two tumor cells with clearly defined cross-striations.

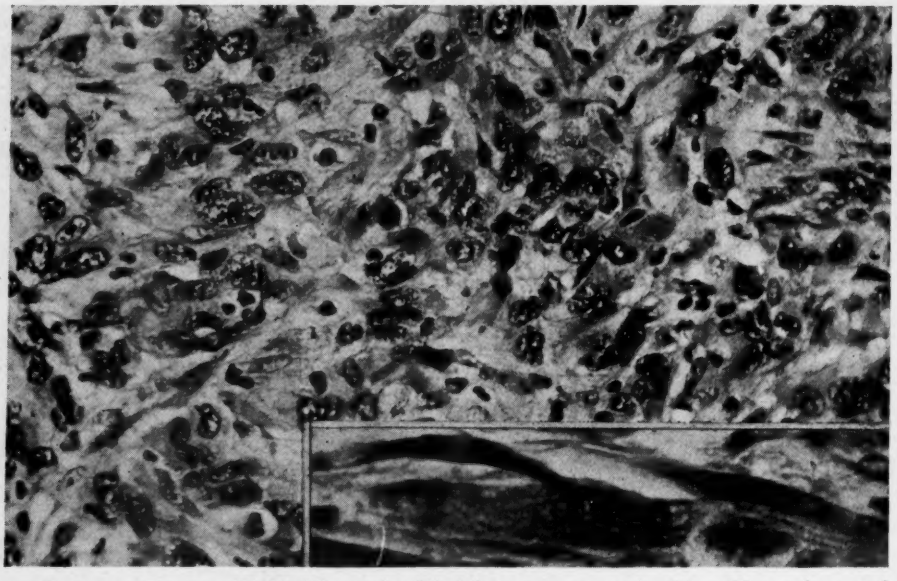


FIG. 10.—Case 12 (Table No. 119): Rhabdomyosarcoma of axilla. Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. The highly magnified inset below shows two cells with faint poorly defined cross-striations.

Microscopic (P & S 16699): The tumor is made up of many very large amorphous to rounded syncytial masses with one or more large hyperchromatic nuclei and clearly defined nuclear markings. Some are vacuolated. Strap cells are also present but uncommon. Rather vague cross-striations but no definite longitudinal fibers are found. The cells have cytoplasm which varies from neutrophilic to strong acidophilic (Fig. 10).

Case 13.—(Table No. 120): M. G., a 69-year-old male Mexican. Eleven months before admission, following a strain from lifting a heavy object, a mass appeared in the right anterior axillary line. After five months it was the size of an orange and was excised. It recurred in the scar and when removed the second time it measured 8.5 x 5.5 x 7 cm., and could be moved over the fourth, fifth and sixth ribs. Fifty milligrams of radium

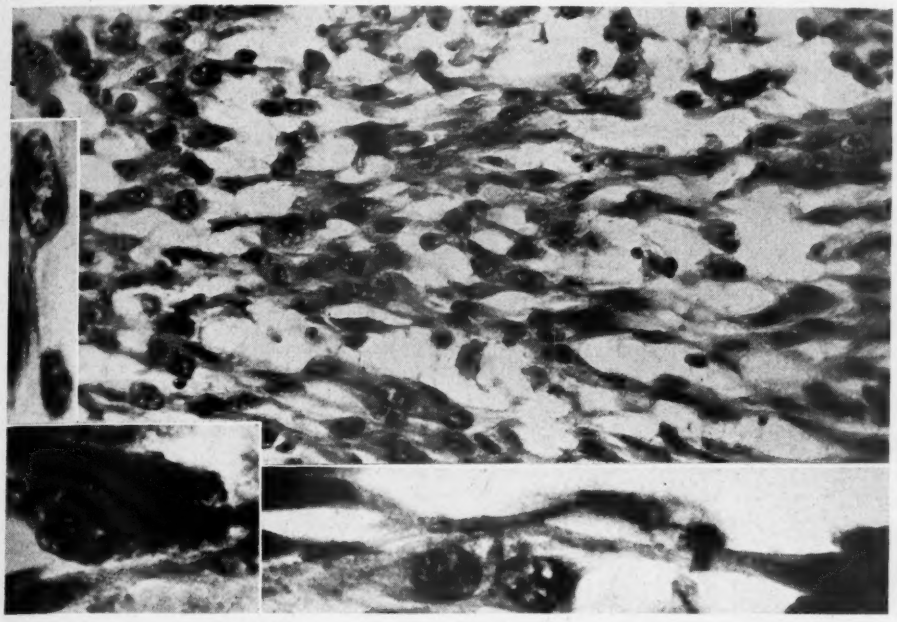


FIG. 11.—Case 13 (Table No. 120): Rhabdomyosarcoma of anterior chest wall muscles. Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. The highly magnified cells below and to the left show strap cells and a giant cell with faintly defined cross-striations.

was put in the wound. When cut open the tumor was soft, light pinkish-gray with darker areas of necrosis. He died six months later. The material was submitted by Dr. A. O. Severance of the Nix Laboratories, San Antonio, Texas.

Microscopic (S. P. 17403): The tumor is made up of long slender strap cells with strongly acidophilic cytoplasms and some giant cells of small size. Cross-striations are demonstrated with difficulty (Fig. 11), but no longitudinal fibers are found.

Case 14.—(Table No. 121): M. R., a female, age 66. Two years and eight months before operation she noticed a small purple nodule on the medial aspect of the right foot at the arch. It grew slowly beneath intact skin. It was only occasionally painful. It was locally excised, but recurred three months later and continued to grow for 11 months, forming a large fungating ulcerated mass (Fig. 12). This time the foot was amputated at the Ellis Fischel State Cancer Hospital, Columbia, Mo. I am indebted to Dr. Lauren V. Ackerman, Director of the Hospital, for the gross photograph and the sections.

Microscopic (S. P. 23294): The tumor is made up largely of long slender cells resembling fibroblasts which grow in bundles accompanied by well-developed collagen and

FIG. 12.—Case 14 (Table No. 121) : Rhabdomyosarcoma of the foot.

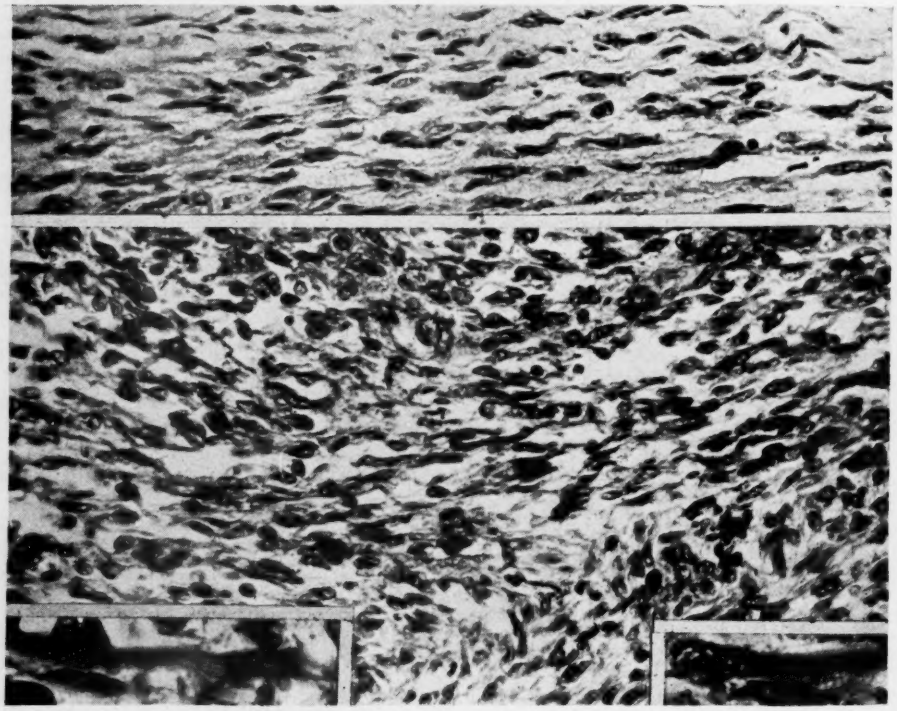


FIG. 13.—Case 14 (Table No. 121) : Photomicrograph (x 410 and x 1260). Masson's acid fuchsin trichrome stain. At the top is shown the fibrosarcoma-like area, below the less fibrous area with many strap cells. The highly magnified cells at the bottom with cross-striations were found in the latter area.

reticulin fibers. In one area there are fewer connective tissue fibers, the cells are more plump, and sometimes rounded. With Masson's trichrome stain it is possible to recognize that the cytoplasm of some of these cells is strongly acidophilic and that there are clearly defined cross-striations in a few of the small, plump, elongated cells and racquet-shaped forms. With the other stains used (eosin methylene blue and phosphotungstic acid hematoxylin) these features are so inconspicuous that they could very easily pass unnoticed (Fig. 13).

Summary. This study shows that, perhaps because it is so rare or so seldom recognized, painfully little information has accumulated in the past 90 years about rhabdomyosarcoma of the peripheral muscles. It is very difficult to form any clear mental picture of a tumor so variable that in one instance the clinical course from onset of symptoms until death was only two months (Case 90), while in another the tumor still persisted after 50 years (Case 38). Microscopically, the tumor is characterized by the presence of strap and racquet-shaped cells in which it is sometimes possible in good preparations to demonstrate cross-striations and longitudinal myofibrils, and by giant cells with peripherally arranged vacuoles causing the cell to resemble a spider or spider web. The cytoplasm of all these cells is more or less strongly acidophilic. Grossly, the tumors are found in or adjacent to striated muscles in various parts of the body but most commonly in the thigh and leg. The size is very variable but they seldom reach very great dimensions. The consistency also is variable but as they do not have a very high content of collagen, they are not apt to be extremely hard. Invariably, they infiltrate insidiously and metastases through the blood and lymphatic channels are not uncommon (31.5 per cent), with the lungs as the most favored repository. Records of only four symptom-free five-year survivals are reported among the 121 cases, 108 of which received treatment. One of these was treated by amputation alone, one by excision alone, and the other two by excision and radiotherapy. It should be noted, however, that long survivals of from nine to 50 years, with persisting tumor, are reported. If this tumor is to be cured more often, it is evident that extensive removal of the primary growth must be done earlier and more drastically with greater sacrifice of grossly healthy tissues about the growth. This need not always mean amputation. The writer feels very strongly that tumors of [illegible]oft-parts and bones should not be attacked without preliminary biopsy. If this is done carefully there should be no danger of tumor metastasis. Armed with a knowledge of the nature of the growth the most advantageous therapeutic procedure can then be selected.

BIBLIOGRAPHY

Ammuntegui, G.: Sarcomas primitivos de los musculos. Semana méd., **21**, 639, 1914.

Ardoin, G.: Sarcome rhabdomyoblastique de la région tempero-occipitale. Bull. Assoc. franc. p. l'étude du cancer, **18**, 255, 1929.

Benison, R. L.: Sarcoma of Muscles. J. Internat. Coll. Surg., **3**, 460, 1940.

Bérard: Tumeur embryonnaire du muscle strié. Lyon méd., **77**, 52, 1894.

Bick, E. M.: Skeletal Muscle Sarcoma. ANNALS OF SURGERY, **99**, 949, 1934.

Billroth, T.: Über eine eigentümliche Geschwulst der Muskeln (myoma cysticum). Virchows Arch. f. Path. Anat., **9**, 172, 1856.

Bolãnos, J. M., and Despaigne, E.: Contribution al estadio de los rhabdomiomas de la lengua. Bol. Liga contra el Cancer, **6**, 97, 1931.

Buhl, L.: Wahres, rezidivierendes Myom. Ztschr. f. Biol.. **1**, 263, 1865.

Burgess, A. M.: Malignant Rhabdomyoma with Multiple Metastases. J. Med. Research, **29** (N. S. 24), 447, 1914.

Burke, E. M.: Sarcoma of the Soft Tissues. Am. J. Cancer, **35**, 234, 1939.

Cappell, D. F., and Montgomery, G. L.: On Rhabdomyoma and Myoblastoma. J. Path. & Bact., **44**, 517, 1937.

Charache, H.: Traumatic Rhabdomyosarcoma of the Thigh. Am. J. Surg., **32**, 530, 1936.

Danciger, J. A., and Warren, J.: Rhabdomyosarcoma Case Report. J. Pediat., **19**, 223, 1941.

De, M. N., and Tribendi, B. P.: Skeletal Muscle Tissue Tumor. Brit. J. Surg., **28**, 17, 1940.

De Casto Freire: Rabdomioma congenito de extremodade anterior da lingua. Tip. do Comercio, Lisboa, 1922 (cited by Lino).

Desmarest, E., and Masson, P.: Sarcome du muscle biceps fémoral chez un homme de 80 ans. Ablation sous anesthésie rachidienne. Guérison. Bull. Soc. Anat. de Paris, **14**, 449, 1912.

Distefano, G.: Istogenesi e classazione dei rabdomiomi benigni e maligni. Tumori, **10**, 293, 1936.

Engelbreth-Holm, J.: Tumorer udgaaende fra tvaerstribet muskulatur. Hospitalstid, **79**, 905, 1936.

Fitzwilliams, D. C. L.: Hindquarter Amputation for Sarcoma. Proc. Roy. Soc. Med., **31**, 9 and 548, 1938.

Frank, L. W., Enfield, C. D., and Miller, A. J.: Rhabdomyosarcoma of the Neck. ANNALS OF SURGERY, **104**, 431, 1936.

Fuginami, A.: Ein Rhabdomyosarkom mit hyaliner Degeneration (cylindrom) im willkürlischen Muskel. Virchows Arch. f. Path. Anat., **160**, 203, 1900.

Genevet: Étude anatomo-pathologique du rhabdomyome en général et en particulier du rhabdomyome malin. Thèse de Lyon, 1900.

Geschickter, C. F.: Tumors of Muscle. Am. J. Cancer, **22**, 378, 1934.

Glasunow, M.: Úber unreife, begrenzt und destruierend wachsende Rhabdomyoblastome. Frankfurt. Ztschr. f. Path., **45**, 328, 1933.

Gordon Taylor, G.: On Sarcoma of the Muscles and the Connective Tissue Spaces of Limbs. Brit. J. Surg., **28**, 1, 1940.

Haagensen, C. D., and Krehbiel, O. F.: The Morphology of the Sarcomas Produced by 1:2:5:6-Dibenzanthracene. Am. J. Cancer, **26**, 368, 1936.

Halley, G.: Rabdomiosarcoma. Tumor primitivo del miembro inferior izquierdo y tumor metastásico de la región inguinal izquierda. Bol. Liga contra el cáncer, **16**, 383, 1941.

Harper, H. Y., and Feder, J. M.: Rhabdomyosarcoma: Report of Case Presenting Unusual Features, with Reference to Age, Race, Site of Origin and Manner of Growth. Surgery, **6**, 76, 1939.

Howe, C. W., and Warren, S.: Myoblastoma. Surgery, **16**, 319, 1944.

Johan, B., Jr.: Ein Rhabdomyosarcoma chondro-myxomatosum des Oberarmes. Frankfurt. Ztschr. f. Path., **22**, 50, 1919.

Jônsson, G.: Malignant Tumors of the Skeletal Muscles, Fasciae, Joint Capsules, Tendon Sheaths and Serous Bursae. Acta Radiol., Supp. **36**, pp. 1–304, 1938.

Kirschbaum, J. D.: Myosarcoma of the Diaphragm. Am. J. Cancer, **25**, 730, 1935.

Kolmer, W.: Partieller Riesenwuchs in Verbindung mit grossen Rhabdomyon bei einer Schleie (Tinca tinca). Virchows Arch. f. Path. Anat., **268**, 574, 1928.

Landois, F.: Úber die primären Muskelsarkome. Berl. klin. Wchnschr., **49**, 2055 and 2274, 1912.

Lenormant, C.: Sur les sarcomes des muscles. Schweiz. med. Wchnschr., **68**, 449, 1938.

Lepage, R.: Un cas de Rabdomyome des Regions Maxillaires et sublinguales. J. de méd. de Paris, **54**, 690, 1934.

Ligas, A.: Rabdomioma maligno del quadricipite femorale. Arch. ital. di chir., **58**, 365, 1940.

Lino, G.: Contributio allo studio dei tumori rari della lingua; della istogenesi del rhabdomioma. Tumori, **14**, 373, 1928.

Lochrane, C. D.: Rhabdomyosarcoma of Corpus Uteri. Proc. Roy. Soc. Med., **26**, 1429, 1933.

MacCallum, P.: Rhabdomyoma of the Extremities. Australian & New Zealand J. Surg., **2**, 296, 1933.

Marchand, F.: Uber ein Geschwulst aus quergestreiften Muskelfasern mit ungewohnlichen Gehalte an Glykogen in einigen fötalen Geweben. Virchows Arch. f. Path. Anat., **100**, 42, 1885.

Meyenburg, H. von, in Henke und Lubarsch: Handb. d. Spez. Path. Anat. u. Histol., ix/1, 1929, p. 468 ff.

Montpellier, J.: Les rhabdomyomes. Caractères généraux et variétés anatomo-cliniques. Bull. Assoc. franc. p. l'étude du cancer, **18**, 538, 1929.

Morpurgo, B.: Mioblastomi. Arch. per le sci. med., **59**, 229, 1935.

Morpurgo, B.: Künstliche Erzeugung eines sehr atypischen myoblastoms der Zunge bei einer weissen Ratte. Centralbl. f. allg. Path. u. Path. Anat., **63**, 1, 1935.

Moulonguet, P., and Pollosson, E.: Sarcomes des Muscles et des coulées conjonctives des membres. J. de Chir., **52**, 501, 1938.

Muller, H. R.: Traumatic Rhabdomyosarcoma Following Successive Fractures of the Femur. J. Cancer Research, **2**, 393, 1917.

Nettleship, A.: Spontaneous Mouse Rhabdomyosarcoma. J. Nat. Cancer Inst., **3**, 563, 1943.

Oro, K.: Über ein bösartiges myoblastenmyom ausgehend von muskulaturen der Beugeseite des linken Vorderarmes veranlasst durch Trauma. Tr. Soc. Path-Jap., **24**, 571, 1934.

Oswald, W.: Rhabdomyosarkom des Hals mit ausgedehnter Metastasierung. Frankfurt. Ztschr. f. Path., **55**, 60, 1941.

Peery, T. M., and Smith, W. A.: Rhabdomyosarcoma of Diaphragm. Am. J. Cancer, **35**, 416, 1939.

Pendl: Über ein congenitales Rhabdomyome der Zunge. Ztschr. f. Heilk., **18**, 457, 1895.

Peyron, A.: Sur l'Évolution Neoplasiques des fibres musculaires striées dans le sarcome infectieux des Oiseaux. Bull. Assoc. franc. p. l'étude du cancer, **10**, 23, 1921.

Peyron, A.: Les Tumeux des Muscles. Atlas du Cancer, Septiéme fascicule. Félix Alcan, Paris, 1929.

Pogogeff, I. A., and Murray, M. R.: Regeneration of Adult Mammalian Skeletal Muscle *in vitro*. Science, **101**, 174, 1945.

Prochazka, G.: Rhabdomyoma in a Cow Fetus. časop. lék. česk., **64**, 1476, 1925.

Ravich, A., Stout, A. P., and Ravich, R. A.: Malignant Granular Cell Myoblastoma Involving the Urinary Bladder. ANNALS OF SURGERY, **121**, 361, 1945.

Rakov, A. I.: Malignant Rhabdomyoblastomas of Skeletal Musculature. Am. J. Cancer, **30**, 455, 1937.

Ribbert: Beiträge zur kenntnis des Rhabdomyoma. Virchows Arch. f. Path. Anat., **130**, 249, 1892.

Richmond, S. M.: Rhabdomyosarcoma of Skeletal Muscle: With Report of 2 Cases. Texas State J. Med., **35**, 407, 1939.

Roskin, G.: La cellule myomateuse et quelques problémes relatifs à la cellule musculaire. Bull. Assoc. franç. p. l'étude du cancer, **23**, 172, 1934.

Rütz, A.: Angeborenes Rhabdomyom der Zunge. Med. Klin., **22**, 1072, 1926.

Ryan, E. J.: Rhabdomyosarcoma of the Diaphragm. Cleveland Clin. Quart., **6**, 304, 1939.

Sabrazès, and Peyron, A.: Persistence de la différenciation contractile (double striation) sur les éléments Néoplasiques en voie de metastase dans les Rhabdomyomas. Compt. rend. Soc. de biol., **92**, 617, 1925.

Scott-Carmichael, E.: Primary Sarcoma of Both Biceps Muscles. Brit. Med. J., 1, 15, 1913.

Shanin, A. P.: Early Diagnosis of Sarcoma of Skeletal Musculature. Sovetskiy Vrach. Zhurnal, August 30 (No. 16), 1201, 1936.

Stewart, F. W.: Radiosensitivity of Tumors. Arch. Surg., **27**, 979, 1933.

Stulz, E., Diss, A., and Fontaine, R.: Myxosarcome de l'aventbras, d'origine musculaire. Bull. et mém. Soc. Anat., **20**, 429, 1923.

Targett, J. H.: Congenital Myxosarcoma of the Neck Containing Striped Muscle Cells. Trans. Path. Soc., London, **43**, 157, 1892.

Temofeevskiy: Question of the Capacity of Cells of Malignant Neoplasms for Differentiation; Culture of Malignant Rhabdomyoblastoma. Vrach., delo **20**, 569, 1938.

Thomas, E.: Un cas de rhabdomyosarcome de la langue. Ann. méd-chir. de l'Hop. Sainte-Justine, Montréal, **3**, 135, 1940.

Tourneux, J. P., and Gouzi, J.: Tumeurs malignes du psoas. Toulouse méd., **33**, 443, 1932; also Presse méd., **40**, 862, 1932.

Warnery: Du rhabdomyome des muscles striés. Thèse de Bâle, 1918.

Weber, C. O.: Anatomische Untersuchung einer hypertrophische Zunge nebst Bemerkungen über die Neubildung quergestreifter Muskelfasern. Virchows Arch. f. Path. Anat., **7**, 115, 1854.

Wolbach, S. B.: Centrioles and Histogenesis of Myofibril in Tumors of Striated Muscle Origin. Anat. Rec., **37**, 255, 1928.

Wolbach, S. B.: Malignant Rhabdomyoma of Skeletal Muscle. Arch. Path., **5**, 775, 1928.

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The selected essay (or essays) will appear on the program of the forthcoming meeting of the American Urological Association, to be held at the Netherland Plaza, Cincinnati, Ohio, July 22-25, 1946.

Essays must be in the hands of the Secretary, Dr. Thomas D. Moore, 899 Madison Avenue, Memphis, Tennessee, on or before July 1, 1946.

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SUPRACONDYLAR AMPUTATIONS

A SURVEY

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THE FOLLOWING SURVEY covers the results of 149 amputations undertaken on 131 patients on all Surgical Services of the Goldwater Memorial Hospital between July 1, 1939, and January 1, 1945. The great majority of cases are thigh amputations. Of the 16 leg amputations, eight were subsequently submitted to supracondylar procedures. Abbreviations (see Table I) are employed to denote the general classification of the patients. As a result of this study, certain modifications in present procedures in the management of such cases is indicated.

No attempt has been made to outline the severity of the individual case, nor the gravity of its complications. The latter are so varied in their manifestations that they fully deserve separate treatment. Moreover, it should be taken for granted that these patients are all gravely ill and borne down not only by the occlusive vascular disease which leads to the amputation, but also by the manifold complications of generalized arteriosclerosis and of diabetes, or both. Nor are they free from the neoplastic diseases common to this age-group. Nevertheless, in order to indicate the general order to which each patient belongs, we have confined their classification to four groups: arteriosclerosis, diabetes, thrombo-angiitis obliterans, and others. (See Table V.)

Since patients of this age-group (see Tables I, II, III and V) who suffer from diabetes are never free from arteriosclerosis in one or all of its manifestations, all patients under this classification may be considered arteriosclerotics whose disease is complicated by diabetes.

The advent of refrigeration as a form of anesthesia, particularly in view of some enthusiastic reports of its efficacy and life-saving potentialities, quite naturally challenges a comparison between it and the older methods. With this in mind, I have grouped the results of our amputations into Refrigeration, Spinal, and Cyclopropane, according to the method of anesthesia employed.

The results obtained are tabulated in Tables I, II and III. The findings in Table IV indicate (a) that the mortality under refrigeration is almost twice that of either of the other methods; and (b) that not only is the incidence of gas bacillus infection high under refrigeration, but also that this form of infection did not occur at all with the other methods.

These findings prompted a search of the literature for results obtained by other clinics, and the latter, as far as I could gather, are shown in Table VI.

Some of the authors accentuate the fact that refrigeration was used only on the gravely ill, and in certain instances they even attempt—for the sake

TABLE I

REFRIGERATION ANESTHESIA

Recoveries

No.	Name	Age	General Classif.	Extremity	Days P-Op.
1	H. B.	79	As	L thigh	12(?)
2	M. M.	74	Di	L thigh	18
				R thigh	34(G)
3	A. M.	69	Di	R thigh	105(G)
4	G. B.	70	Di	L thigh	160
5	A. S.	59	Di	R thigh	160
6	T. C.	62	As	R leg	
				R thigh	28
7	S. B.	57	Di	L thigh	66
8	J. F.	79	Di	R thigh	32
9	C. H.	54	As	R thigh	240
10	S. L.	64	Di	L leg	
				L thigh	44
11	W. K.	60	Di	R leg	61
12	S. duB.	60	As	L thigh	148(G)
13	J. G.	56	As	R thigh	66
14	J. H.	70	Di	R thigh	67
15	J. Gr.	74	As	R thigh	135
				L leg	204
16	G. S.	85	As	L thigh	26
17	M. S.	76	As	L leg	
				L thigh	48(G)
18	M. V.	43	As	L thigh	10(?)
				R thigh	15(?)
19	A. O.	57	Di	L thigh	107(G)
20	E. G.	44	TAO	R thigh	31
				L thigh	35
21	C. M.	68	As	R thigh	104
22	J. M.	75	Di	L thigh	66
23	G. R.	83	As	R leg	60
24	C. S.	65	As	R thigh	37
25	K. S.	61	Di	L leg	47
26	M. O.	75	Di	R thigh	8(?)
27	W. C.	67	Di	R thigh	60
28	K. V.	70	Di	R thigh	12(?)
29	J. B.	74	Di	R leg	106
30	C. C.	72	As	R thigh	96
31	J. F.	62	As	R thigh	42
32	M. F.	50	Di	L thigh	12(?)
33	F. E.	60	As	R thigh	56
34	T. F.	60	Di	L thigh	31
35	R. G.	68	As	L thigh	7(?)
36	M. G.	57	As & THR	L thigh(1)*	78
37	G. H.	69	Di	L thigh	28
38	M. H.	36	L-Ed	L thigh	150
39	L. K.	70	Di	L thigh	7(?)
40	J. L.	72	As	L thigh	17
41	L. M.	54	Di	R thigh	15
42	W. P.	61	As	L thigh	50
43	O. S.	57	As	R thigh	48
44	J. M.	61	As	L thigh	9(?)
45	A. S.	70	Di	R thigh	242
46	H. B.	73	As	L thigh	30
47	V. L.	66	As	R thigh	16
48	P. H.	74	Di	R leg	122

Deaths

No.	Name	Age	General Classif.	Extremity	Days P-Op.
49	P. S.	76	Di	R thigh	60(G)
50	R. A.	67	Di	R thigh	21
51	M. A.	72	Di	L thigh	89
52	H. C.	50	Di	L thigh	17
53	J. F.	75	Di	R thigh	21
54	J. K.	85	As	L thigh	2(G)
17	M. S.	76	As	R thigh	10
55	A. T.	80	As	R thigh	1
56	R. W.	68	Di	L thigh	63(G)
57	J. N.	70	Di	L thigh	105
58	S. R.	65	Di	L thigh	130
59	B. P.	71	As	R thigh	7
60	L. R.	70	As	R thigh	4
61	F. M.	75	Di	L thigh	32
62	M. McG.	76	Di	R thigh	On op. table
63	H. W.	58	Di	R thigh	13
64	C. S.	61	Di	R thigh	11
65	J. G.	62	Di & THR	L thigh	23
66	S. DeB.	62	As & Ost	R thigh	2
67	A. A.	61	Di	R thigh	3
68	N. B.	48	Di	L leg	54
69	J. B.	81	As	L thigh	4
70	P. C.	71	As & THR	L thigh	1
71	J. C.	75	As	R thigh	91
72	I. F.	61	As	L leg	(See Cyclo) (G)
36	M. G.	57	As	R thigh(2)*	131
73	J. H.	77	As	R thigh	5
74	H. H.	61	As	L thigh	22
75	R. K.	72	As & THR	L thigh	25
76	A. W.	72	As	R thigh	1
77	T. McC.	74	As	R leg	
				R thigh	17
78	M. M.	77	Di	L thigh	5
79	C. M.	71	As	R thigh	1
80	F. R.	75	Di	L thigh	30
81	O. W.	78	As	R thigh	23
82	L. McM.	62	As	R thigh	116
83	G. B.	79	Di	R thigh	1

SUMMARY OF AMPUTATIONS UNDER REFRIGERATION ANESTHESIA

Total number of amputations	94
(performed upon 83 patients)	
Total number of deaths	36
Amputation mortality	38.2%
Case mortality	43.3%
Total number of gas infections	9
Amputation incidence	9.57%
Case incidence	10.84%

* (1) indicates the first operation; and (2) the second operation.

Abbreviations:

As = Arteriosclerosis Di = Diabetes TAO = Thrombo-angiitis obliterans THR = Thrombosis of chief artery L-Ed = Lymphedema, chronic (etiology not established) Sp.Par = Spinal paraplegia Polio = Poliomyelitis (G) = Gas bacillus infection (*Cl. welchii*) (?) = Records incomplete as to exact date of stump-healing

of the record—to attribute a fatality to a preëxisting disease or to its complication. This would seem a difficult and controversial way to classify success and failure. To us it appeared sufficient to classify a case as a failure when the patient, at death, *showed an unhealed stump,* with varying degrees of infection, suppuration or gangrene, regardless of preëxisting disease or length of the postoperative survival period. On the other hand, all cases with healed stumps were set down as recoveries, although a goodly number subsequently succumbed to preëxisting or other disease.

TABLE II

SPINAL ANESTHESIA

Recoveries						Deaths					
No.	Name	Age	General Classif.	Extremity	Days P-Op.	No.	Name	Age	General Classif.	Extremity	Days P-Op.
84	J. B.	74	As	R thigh	14	93	J. B.	76	As	R thigh	2
85	C. C.	38	TAO	L leg	57	94	A. R.	81	Di	R thigh	8
86	C. G.	74	As	R thigh	17	95	M. W.	62	As	L thigh	2 hrs.
87	J. H.	73	As	L thigh	16	96	C. M.	77	Di	R thigh	18
88	J. J.	66	As	R thigh	64	97	L .G.	72	As	L thigh	14
89	M. R.	66	As & THR	L thigh	9						
90	J. R.	66	As	R leg	391						
91	W. C.	79	As	L thigh	31						
92	G. C.	43	As	L leg(2)*	14						
98	K. D.	69	As	L thigh	11						
15	J. Gr.	74	As	L thigh	91						
99	M. M.	55	As	L thigh	35						

*(2) indicates the second operation.

SUMMARY OF AMPUTATIONS UNDER SPINAL ANESTHESIA

Total number of amputations		17 (performed upon 17 patients)
Total number of deaths:		5
Amputation mortality	29.4%	
Case mortality	29.4%	
Total number of gas infections		0

Some authors, again, compare the results obtained under refrigeration with those of some ten years ago, under the then prevailing methods. They find solace in the infinitely lower death rate now obtained by refrigeration, forgetting, for the moment, the immense contributions made to surgery by the sulfa drugs, penicillin, polyvalent sera, and a great number of other drugs and measures employed at the present time in pre- and postoperative care. This is exemplified in the results we obtained under cyclopropane (see Table III).

A review of some of the literature follows. In no instance did the results obtained under refrigeration, whenever the Allen technic was used, equal those reported by the originators of the method who, indeed, reported a case mortality of 15.5 per cent (see Table VI, 1).

Captain Shaar and coworkers[2] report ten cases under refrigeration, with two deaths, a case mortality of 20 per cent. They are very enthusiastic about this method, although in the same place they report 37 cases under spinal with one death, which yields a mortality of only 2.6 per cent. No mention is made of gas gangrene.

TABLE III

CYCLOPROPANE ANESTHESIA

Recoveries						Deaths					
No.	Name	Age	General Classif.	Extremity	Days P-Op.	No.	Name	Age	General Classif.	Extremity	Days P-Op.
100	R. J.	73	Di	R thigh	95	125	J. B.	70	Di	L thigh	11
101	A. L.	59	Di	R thigh	122	72	I. F.	61	As	L thigh	56
102	J. A.	50	As	L thigh	15	126	W. K.	64	As	L thigh	2
103	J. R.	64	Sp.Par.	L thigh	7(?)	127	E. K.	77	Di	R thigh	9
				R thigh	8(?)	128	E. P.	77	As	L thigh	21
104	M. B.	67	Di	R thigh	95	129	J. R.	82	As	L thigh	10
105	G. C.	65	Di	L thigh	90	130	J. S.	72	As	R thigh	11
106	A. DeC.	68	Di	R thigh	41	131	D. C.	66	As	R leg	23
107	E. D.	61	As	L leg L thigh	561						
92	G. C.	43	As	L leg(1)* L thigh(3)*	424						
108	O. E.	84	As	L thigh	75						
109	M. E.	16	Polio	R thigh	13						
110	M. F.	62	As	R thigh	84						
111	S. G.	73	Di	R thigh	17						
112	J. G.	64	As	L thigh	25						
113	D. K.	57	Di	R thigh	66						
114	P. L.	47	As & frostbite	L leg	10						
82	L. McM.	62	As	L thigh	66						
115	V. LaM.	61	As	L thigh	15						
116	V. M.	52	TAO	R thigh	21						
117	Y. R.	58	Di	R thigh	69						
118	M. P.	72	As	L thigh	76						
119	S. S.	60	As & THR	R thigh	45						
120	F. R.	77	As	L thigh	15						
121	C. St.M.	82	As	R thigh	40						
122	W. S.	78	Di	L thigh	69						
123	J. W.	38	As	R thigh	18						
124	J. S.	50	TAO	R thigh	9(?)						

*(1) indicates the first operation; and (3) the third operation.

SUMMARY OF AMPUTATIONS UNDER CYCLOPROPANE ANESTHESIA

Total number of amputations		38 (performed upon 35 patients)
Total number of deaths:		8
Amputation mortality	21.05%	
Case mortality	22.83%	
Total number of gas infections		0

TABLE IV

SUMMARY

Anesthesia Employed	No. of Amputations	No. of Patients	No. of Deaths	Amp. Mort.	Case Mort.	Gas Bac. Inf. No. of Gas Inf.	Gas Bac. Inf. Amp. Incid.	Gas Bac. Inf. Case Incid.
Refrigeration	94	83	36	38.2%	43.3%	9	9.57%	10.84%
Spinal	17	17	5	29.4%	29.4%	0	0	0
Cyclopropane	38	35	8	21.05%	22.85%	0	0	0

TABLE V

CLASSIFICATION OF PATIENTS

	Average Age	Total No.	No. of Deaths	Case Mortality
Diabetic males	65.8	24	8	33.3%
Diabetic females	66.7	30	14	46.6%
Arteriosclerotic males	68.5	54	17	31.2%
Arteriosclerotic females	66.6	16	10	62.5%
Thrombo-angiitis obliterans	46.0	4	0	0
Others		3	0	0

Glasser and Mersheimer[3] report 17 amputations under refrigeration, with a case mortality of 38.8 per cent (Table VI, 3).

O'Neill[4] (Table VI, 4) reports 50 cases under refrigeration, with a case mortality of 32 per cent, and an incidence of gas gangrene of 4 per cent.

Cayford and Pretty[5] (Table VI, 5) report 22 amputations, with a case mortality of only 18 per cent, and a gas infection incidence of 13.6 per cent.

TABLE VI

CASE REPORTS FROM OTHER CLINICS

1. Crossman, Ruggiero, Allen, *et al.*[1]
   57 amputations (upon 45 patients) under refrigeration
   Number of deaths: 7
   Amputation mortality..... 12.2%
   Case mortality..... 15.5%
   Gas gangrene infections: 1 case—Incidence..... 2.2%
2. Captain Shaar and a group of Naval Officers[2]
   53 amputations, as follows:
   37 cases under spinal, with 1 death; case mortality..... 2.6%
   10 cases under refrigeration, with 2 deaths; case mortality..... 20.0%
   5 cases under local, with 1 death; case mortality..... 20.0%
   No mention is made of gas gangrene
3. Glasser and Mersheimer[3]
   17 amputations under refrigeration, with a case mortality of..... 38.8%
   No mention is made of gas gangrene
   Pneumonia and pulmonary embolism are cited as frequent causes of death in this group
4. O'Neill (Boston City Hospital)[4] reports the following.

	No. of Cases	No. of Deaths	% Mortality
Unoperated cases 1930–39.....	162	162	100%
Operated cases 1930–39.....	270	142	53%
Unoperated cases 1940–43.....	4	4	100%
Operated with refrigeration 1940–43.....	50	16	32%

   Gas gangrene, 2 cases*—Case incidence: 4%
   * Early in series. Since then, every case gets polyvalent serum preoperatively. Dr. O'Neill imputes that if not for this precaution, incidence of gas bacillus infections would be higher.
5. Cayford and Pretty[5]
   22 amputations, with 4 deaths: Case mortality..... 18%
   Gas bacillus infections: 3; Case incidence..... 13.6%
   Note: Refrigeration without tourniquet was used in 18 of the above cases, according to a modification of the McElvenny method.
6. McElvenny[6]
   6 cases—No. of deaths: 1; Case mortality..... 16.6%
   Refrigeration without tourniquet, or freezing
7. Large and Heinbecker[7]
   6 cases—No. of deaths: 0; Case mortality: 0
   Note: Refrigeration plus tourniquet according to new concept based on laboratory evidence on the advantages and disadvantages of refrigeration

But, here, it should be noted that in 18 of the above cases, refrigeration alone, *without a tourniquet,* was employed.

McElvenny[6] (Table VI, 6) reports six cases with one death. This author, in the main, has discarded the tourniquet and uses either refrigeration alone or freezing of the affected limb, without relying on either one for anesthesia during amputation.

Large and Heinbecker[7] (Table VI, 7) report six cases with no deaths, employing refrigeration plus tourniquet, according to a new concept.

The concepts of Doctor Allen, in the main, were accepted. Certain of his contentions, however, particularly with reference to tissue damage under refrigeration, are challenged.

Richards,[8] of Stanford University, on the basis of two clinical cases, offers microscopic proof of damage to muscle, nerve, and blood vessels, of tissues submitted to refrigeration. Of particular interest, in addition, are the conclusions of Richards, which he reached with reference to one of these cases. The latter was a 52-year-old diabetic female who had suffered an embolic occlusion of the left femoral artery. Embolectomy failed to restore the circulation to the limb, and it was decided to submit the limb to refrigeration in order to reduce its metabolic requirements to a minimum, thus affording opportunity for the possible development of an adequate collateral circulation.

For 13 days, the thigh was maintained at an approximate skin temperature of 18° C., and the leg at 8° C., without a tourniquet. Although true gangrene of the limb did not occur and infection did not appear, it became obvious on the 13th day that the limb was not viable, and a guillotine amputation, under refrigeration, was performed. Twenty-two days postoperative, there was no closure of the stump wound, and the patient died exhibiting the symptoms of either acute heart failure or pulmonary embolus. Postmortem was not obtained.

The amputated limb was gangrenous, but infection of the tissues and necrotic changes were minimal. The popliteal vessel was occluded by an organizing thrombus. "As soon as the thrombus was removed it was apparent the blood had not coagulated in the peripheral structures, for a radiopaque mass could be easily injected into the popliteal vessels and made to flow down the leg. Even the minutest vessels of the foot were patent. However, microscopic studies of the muscle, nerve, blood vessels and skin of the amputated limb were discouraging, for they showed degeneration above referred to."

Doctor Richards remarks: "This isolated experience of a limb which was the seat of an unsuccessfully removed arterial embolus was not gratifying. Although cooling of the anoxic limb had retarded the metabolic needs of the tissues and prevented gross necrotic changes, we felt it had not prevented gangrene, had caused the available collateral blood vessels to contract, and had retarded both the stimulus for, and rate of, growth of new collateral channels."

Our knowledge of the action of refrigeration on normal tissues has recently been augmented by the experimental work of a group[9, 10, 11] from the Washington University School of Medicine and the Barnes Hospital, St. Louis, Mo. The results of their labors are summed up as follows:

1. During the refrigeration period, there is inhibition of the *inflammatory reaction response,* which becomes slightly greater during the period following refrigeration.

2. During the refrigeration period, there is *inhibition of response to Streptococcus hemolyticus,* while after refrigeration the tissues exhibit a *decreased* resistance to these bacteria.

3. *There is inhibition of wound healing,* the delay being roughly proportional to the duration of the cooling period, and, finally,

4. Wounds of refrigerated tissues showed a much higher incidence of *gross infection with suppuration* than did the uncooled controls.

In a recent article, Large and Heinbecker[7] offer a comprehensive review of the subject of refrigeration. These authors summate the advantages and disadvantages of refrigeration as well as the application of the tourniquet, as follows:

1. "The benefits of refrigerating an extremity include loss of sensation and diminution of absorption of noxious agents from the cooled area, while the disadvantages lie in a subsequent delay in wound healing, a greater risk of infection, and a varying degree of actual damage to refrigerated tissues left *in situ*.

2. "The benefits of the application of a tourniquet to a limb refrigerated *above* the proposed level of amputation include anesthesia and the elimination of absorption of noxious agents, with increased duration of viability, of the completely ischemic tissues, while the ill effects, again, include delayed wound healing, greater risk of infection, and actual tissue damage to the refrigerated stump.

3. "The benefits of refrigeration with the application of a tourniquet *below* the proposed level of amputation of a limb, as in other instances, include loss of sensation and elimination of absorption of noxious agents from the part; the further advantage of eliminating delay in wound healing and the spread of infection also is assured."

Large and Heinbecker[7] also mention that the disadvantage of the Allen method appears to lie in the fact that much of the cooled and, therefore, damaged tissue is not excised; they recommend that all refrigerated tissue should be removed at operation, and show that this can be done *by applying the tourniquet and the cold distal to the level of amputation.*

The results obtained with the present series of cases under refrigeration according to the Allen technic appear to corroborate, clinically, the deductions put forward by Large, and coworkers. In addition, one is impelled to the conclusion that the high incidence of gas bacillus infections in this series, as well as in that reported by Cayford and Pretty,[5] and O'Neill,[4] may be explained by the fact that an amputation stump, rendered anoxic by refrigeration and/or tourniquet, offers an ideal field for the growth of the obligate anerobic *Clostridii.*

SUMMARY

1. The results of 149 amputations, the great majority supracondylar procedures, are reported.

2. The results, tabulated according to the form of anesthesia employed, show an amputation mortality of 38.2 per cent with refrigeration according to the Allen technic (Table I); an amputation mortality of 29.4 per cent under spinal (Table II); and an amputation mortality of 21.05 per cent under cyclopropane (Table III).

3. An amputation incidence of 9.57 per cent of gas bacillus infections occurred with refrigeration according to the Allen technic (Tables I and IV).

No gas bacillus infections occurred in either of the other groups (Tables II, III and IV).

4. The clinical results obtained under refrigeration in this hospital, as well as in some others[3, 4, 5] appear to corroborate the laboratory findings of Large and Heinbecker.[10, 11]

5. Modifications in procedure of refrigeration as applied to amputations, and suggested by Large and Heinbecker,[7] have been adopted and are now being carried out on a new group of cases. Although the results in this new group are good, the group as yet is too small to warrant conclusions or reporting.

REFERENCES

1 Crossman, L. W., Ruggiero, W., Hurley, V., and Allen, F. M.: Reduced Temperatures in Surgery. Arch. of Surg., **44**, 139–156, 1942.

2 Shaar, C. M., Jones, D. T., and Lehan, T. R.: Refrigeration Anesthesia. Surg. Clinics of N. A., **24**, No. 6, 1326–36, 1944.

3 Glasser, S. T., and Mersheimer, W. L.: Refrigeration Anesthesia of the Extremities. Am. Jour. of Surg., **62**, 231–234, 1943.

4 O'Neill, E. Everett: The Use of Refrigeration in Amputations and Peripheral Vascular Disease. N. Engl. J. M., **230**(8), 209, February 24, 1944.

5 Cayford, E. Howard, and Pretty, H. Gurth: Refrigeration Anesthesia, *etc.* ANNALS OF SURGERY, **121**, No. 2, 157–163, 1945.

6 McElvenny, R. T.: Refrigeration in Trauma of the Extremities. Surg. Clinics of N. A., **25**, No. 1, 192–209, 1945.

7 Large, Alfred, and Heinbecker, Peter: Refrigeration in Clinical Surgery. ANNALS OF SURGERY, **120**, No. 5, 707–715, 1944.

8 Richards, Victor: Refrigeration Anesthesia. ANNALS OF SURGERY, **119**, No. 2, 178–200, 1944

9 Bruneau, Jacques, and Heinbecker, Peter: Effects of Cooling on Experimentally Infected Tissues. ANNALS OF SURGERY, **120**, No. 5, 716–726, 1944.

10 Large, Alfred, and Heinbecker, Peter: The Effect of Cooling on Wound Healing. ANNALS OF SURGERY, **120**, No. 5, 727–741, 1944.

11 Large, Alfred, and Heinbecker, Peter: Nerve Degeneration Following Prolonged Cooling of an Extremity. ANNALS OF SURGERY, **120**, No. 5, 742–749, 1944.

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